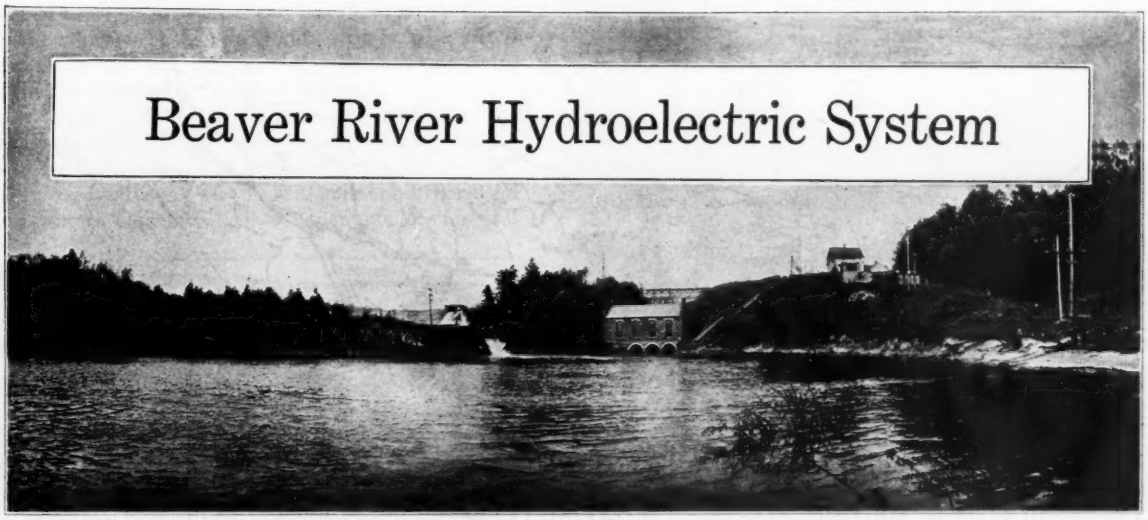
POWER PLANT ENGINEERING

Trade Mark, Reg. U. S. Pat. Office

VOL. XXVII CHICAGO, OCTOBER 15, 1923 No. 20



Beaver River Hydroelectric System

SYSTEM COMPOSED OF FIVE SMALL PLANTS IS AN INTERESTING EXAMPLE OF EFFICIENT UTILIZATION OF SMALL WATER POWER RESOURCES. BY R. T. LIVINGSTON*

IF YOU TAKE a map of New York State and examine it carefully, you will find that the northwest portion of this state is a country abounding in small mountain rivers which present unlimited possibilities for the development of hydroelectric power. For the most part, these streams have large drops in short distances in the form of a series of small water falls, though in some cases heads well over 100 ft. are found, as for example, the fall of 163 ft. on the Deer River near Copenhagen. Further, for the most part, these falls are located near or within reasonable transmission distance of the cities or towns of this part of the state and in fact the principal city of this region, Watertown, was so named because of the large amount of available power to be found within the city limits.

Though originally a farming country, it deserted its original employment as the soil is sandy and not at all fertile and while dairying still employs a large amount of capital and population, manufacturing and especially paper making probably surpasses it, not only as to numbers employed, but even more especially as to capital invested. The large amount of available water power and the proximity of the Adirondack forests have made possible the development of these paper mills and few towns situated on rivers are found that have not a paper or a pulp mill. These paper and pulp mills again give an almost ideal opening for the further development of hydroelectric power, for they work 24-hr. a day, seven days a week and in consequence have an extremely high load factor. Many of these mills have, at present, water wheels directly coupled to their pulp grinders; but in almost every case they buy outside power for the rest of their machinery and in some cases they are selling their water rights with the idea of having the available water developed more economically and then completely electrifying their equipment.

The Northern New York Utilities, Inc., is a public service corporation with its home office in Watertown, supplying electric light and power to the majority of the towns and cities in this district but also having a large number of paper mills as customers. Their power production system consists of a large number of comparatively small hydroelectric plants situated on the Black and Oswegatchie rivers or their tributaries and a steam auxiliary plant situated in Watertown, all interconnected. In this article will be described the most complete development of any one river that the utilities have, i. e., that on the Beaver River, one of the tributaries of the Black.

WATERSHED RECEIVES HIGH PRECIPITATION

This is a small river whose watershed is situated on the southwesterly slope of the Adirondack Plateau. It heads in Lake Lila near the hamlet of Nehasane at an elevation of about 1720 ft. above sea level and flows in a general westerly direction through Nehasane Lake, the Stillwater Reservoir and Beaver Lake; then, making sev-

* Mechanical Engineer in charge of water power courses, Columbia University, New York City.

eral falls, it flows into the Black River at Castorland, as may be seen in Fig. 2, at an elevation of about 730 ft. above sea level. In its total length of about 49 mi., it has a drop of 990 ft. and its drainage area is 338 sq. mi. As this watershed lies on the slope of the Adirondacks and is swept by the prevailing westerly winds, it receives from these moisture laden winds of the Great Lakes region one of the highest annual precipitations of any watershed of the state, being as high as 53 in. in some places and probably running close to 46 in. as an average. The average run-off as taken at Eagle Falls for a period of 16 yr., was approximately 30 in., which is about 65 per cent of the rainfall and represents about 2.3 cu. ft. per sec. per sq. mi.

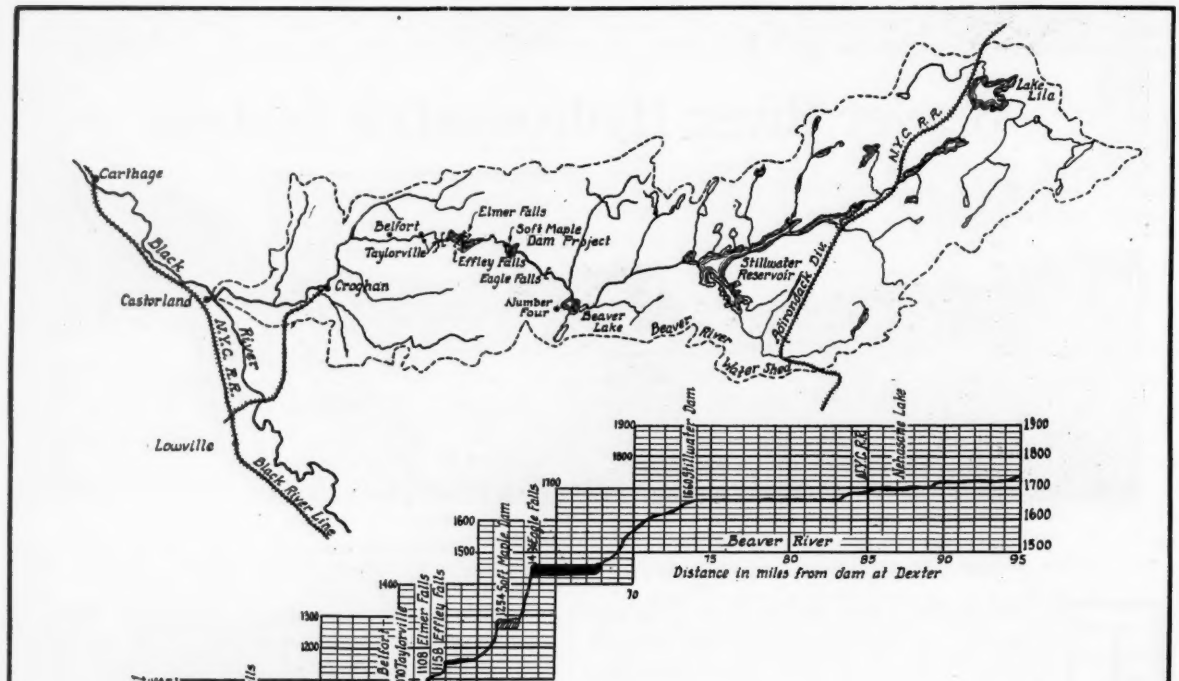


FIG. 2. GENERAL MAP OF BEAVER RIVER SYSTEM

This river, being one of the tributaries of the Black, has been examined by The Conservation Commission of the State of New York for its power and storage possibilities and it is from the report of this commission that the rain-fall and run-off data given in this article are taken. In the year 1887, the State of New York opened the Stillwater Reservoir, situated 32 mi. above the entrance to the Black River and above the greater part of the fall of the river. This reservoir has a capacity of 900,000,000 cu. ft., and a drainage area of 178 sq. mi. This reservoir is attended and helps to a great extent in regulating the flow of the river which would otherwise be exceedingly "flashy" owing to the precipitous nature of the greater part of the watershed and the large amount of bare rock.

In a report regarding the proposed building of various reservoirs on the upper reaches of the Beaver River The Conservation Commission of the State of New York states that "the upper part of the Beaver River watershed affords opportunities * * * favorable for water storage. Natural impounding basins of more than sufficient capacity to completely control the flow at Eagle Falls are available and a high degree of regulation is commercially feasible. With 6 B.C.F.* of storage above Beaver Lake, it is estimated that a constant flow of about 440 sec. ft. could be maintained at Effley Falls and 490 sec. ft. for 60 per cent of the time." The report further states that the building of a dam at Lake Lila to impound 2.7 B.C.F. and the raising of the level of the present Stillwater Reservoir so as to impound an additional 0.9 B.C.F. is the most feasible plan. It was originally intended to raise the level of Beaver Lake, but on account of the large number of cottage owners this was discarded as too expensive. Under what is known as the "Machold Law," the Black River Regulating District was organized and it now has entire charge of regulating matters over the Black River watershed including tributaries. Their plan now proposes a reservoir of 4.5 B.C.F. at Stillwater, thereby eliminating the Lake Lila plan and leaving the question of storage in Beaver Lake to the future. Work has already been started under this plan and it is hoped to have the "New Stillwater Reservoir" in operation by the summer of 1925.

* B.C.F. = Billion Cubic Feet = unit of storage.

This reservoir will be a very great help in increasing the dry-period flow and is the most feasible of all the plans submitted.

Water rights on the Beaver River from Eagle Falls to and including Bellfort are owned by The Northern New York Utilities. Between these points, the river has a fall of 503 ft.; that is to say, between the elevation of the head water at Eagle Falls and the tail water at Bellfort there is a difference of 503 ft. Of this 503 ft., 375 ft. are at present utilized and construction is under way to utilize 382 ft. It is also proposed to install one additional plant which will utilize a large part of the remaining 121 ft. When this last plant is completed, the total head between these two points will be so utilized that except in one case the tail water level of one plant will form the head water level of the next.

There are at present five plants on this section of the river: Eagle Falls, Effley Falls, Elmer Falls, Taylorville and Bellfort, which utilize heads of 139, 49, 37, 103, and 47 ft. respectively. In the last four cases, the head and tail waters coincide. All these plants are or will

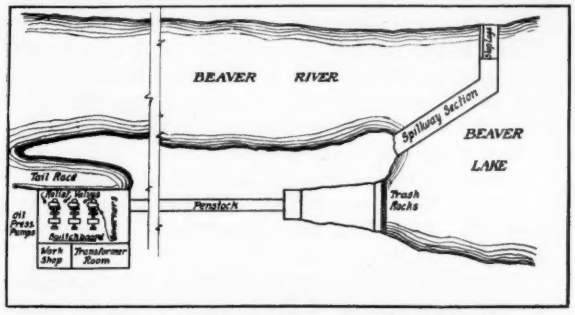


FIG. 3. PLAN OF EAGLE FALLS DEVELOPMENT

be interconnected and will use the same water; in consequence, the regulation and control of the water presents an interesting problem and should be as near ideal as possible to have it. With so many generators on the line, the speed regulation of the turbines should be excellent. Each plant has a pond of sufficient area so that it is not usually necessary to use a greater draft than 2 to 3 ft. and the maximum draw-down, that on Eagle Falls, is seldom greater than 6 ft. The uppermost plant on the Beaver River, owned by the Northern New York Utilities is Eagle Falls, about 5 mi. from the hamlet of Number Four, a summer and hunting resort on Beaver Lake, and about 14 mi. from the town of Croghan, see Fig. 3. At this point, the Beaver River has a drainage area of about 230 sq. mi. and the flow at present varies from about 110 sec. ft. over the whole year to about 500 or 600 sec. ft. for 60 per cent of the time, though in flood periods it may be as much as several thousand. The dam, with a spillway 185 ft. long, of concrete, situated at the crest of Eagle Falls where there is a narrow rock gorge, forms a pond of 87 acres in extent which may be increased by the use of flash boards. On the southerly end of this dam in a separate concrete structure are the trash-racks through which the water flows to a canal excavated in the solid rock about 500 ft. long. At the lower end of this canal are the head gates and from these head gates the water is led through a riveted steel penstock 9½ ft. in diameter and ½ mi. long to the turbines. Views of this plant are shown in Figs. 4 and 5.

Details of Eagle Falls Power House

Eagle Falls power house, situated on the southerly bank of the river, is a concrete structure built in 1914. The turbines, manufactured by the S. Morgan Smith

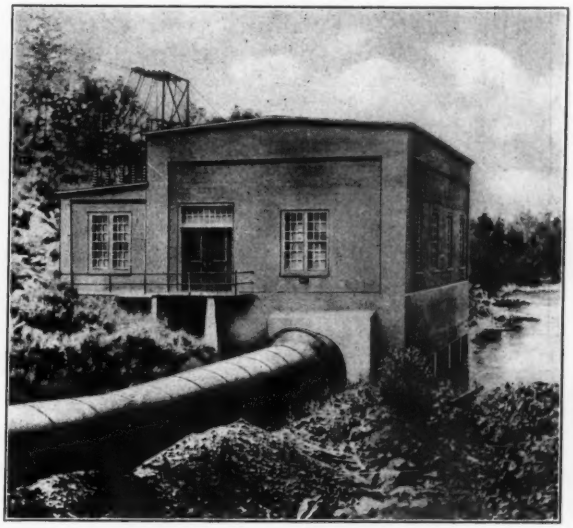


FIG. 4. EAGLE FALLS POWER HOUSE

Co. (see Fig. 6), are horizontal units, Francis type, set in cast-iron scroll cases, designed for 2000 hp. under 135 ft. head at 514 r.p.m. and equipped with governor actuated relay relief valves. The speed of the turbines is regulated by 10,000 ft.-lb., 8¾ by 12 in. type LR, Woodward governors. There are installed at present three units, two of which were put in in 1914, but provi-

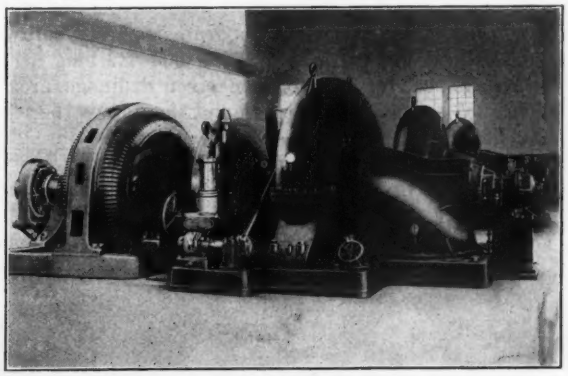


FIG. 5. S. MORGAN SMITH HYDRAULIC TURBINES IN EAGLE FALLS POWER HOUSE

sion has been made for the installation of a fourth unit if desired.

Electrical equipment consists of three alternating current generators of 1350 kw. capacity at 90 per cent power factor, 2300 v. and 377 amp. with direct connected exciters. The current is stepped up for transmission to 22,000 v. by 1500-kv.a., 60-cycle General Electric Co. transformers.

Plant at Effley Falls

Coming down the river from Eagle Falls, the next actual installation is at Effley Falls; but in between the two is the "Soft Maple Dam" project, which is owned

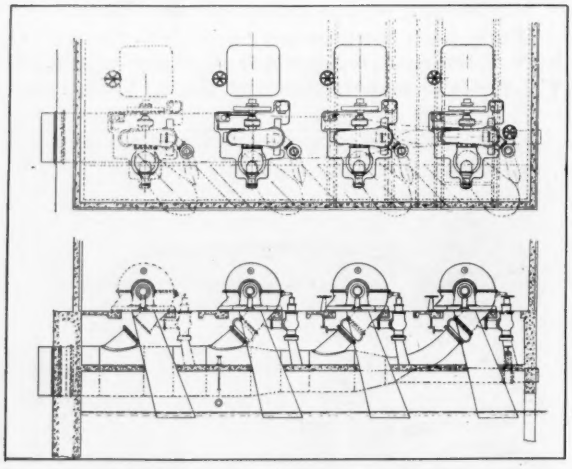


FIG. 6. DIAGRAMMATIC LAYOUT OF TURBINES AT EAGLE FALLS

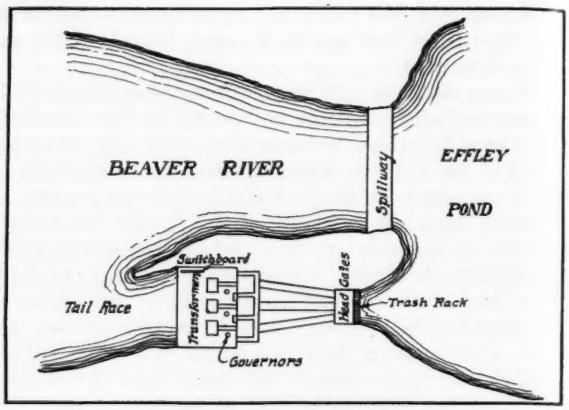


FIG. 7. EFFLEY FALLS PLANT

by the "Utilities." As yet no work has been started here. There is a total fall from the tail-water at Eagle Falls to the head-water at Effley Falls of 121 ft., of which about 117 may be used to produce about 4000 continuous hp. and about 5000 hp. for 60 per cent of the year. The proposed dam, about 850 ft. long and 57 ft. above the river bed, will create a pond of 350 acres which would give the equivalent of one day's regulated flow with a draft of less than 3 ft. The contemplated project will have a pipe-line a little more than ½ mi. in length leading to a power house on the southerly side of the river and which would be at the head of Effley Pond.

At Effley Falls there are a number of alterations now under way, but the present plant, a plan of which is shown in Fig. 7, has a separate concrete spillway dam of the gravity type, about 600 ft. long which creates a head of 49 ft. The river drainage area is about 255 sq. mi. at this point and the flow is therefore obviously but little greater than at Eagle Falls. The head gates are in a separate concrete structure to the south side of the main section of the dam and the water is led from the head gates through three 5-ft. riveted steel penstocks about 130 ft. long. The power house, shown in the headpiece and in Fig. 8, built of native granite on a concrete sub-structure, is situated on the south side of the stream below the crest of the ridge that formed the falls. The turbine equipment consists of three horizontal units in cylindrical casings and with cylinder gates. Two of the units are Hydraulic Turbine Corp. and the third is an S. Morgan Smith unit. All three units have replaced the original ones and all are set in S. Morgan Smith casings. Lombard governors regulate the speed of the wheels. The generators are in all cases General Electric Co. generators of 2300 v. and running at 360 r.p.m., two are of 101 amp. and the third is for 176. This third unit is the new S. Morgan Smith unit last installed.

Current is stepped up to 22,000 v. for transmission into the main system of the company. At the present time the usual draw-down of the pond is 2—3 ft. with a maximum of 6—7 ft.

Work under construction consists of raising the crest of the dam to give a head of 55 ft. with a possibility of still further increasing it to 57 ft. by the use of flash boards. This will give a pond of 320 acres. When this head is increased, a more complete utilization of the flow of the water in the stream will be effected by the installation of one new S. Morgan Smith turbine by 2000 hp. supplied by an 8 ft. riveted steel penstock 150 ft. long and governed by a Woodward governor.

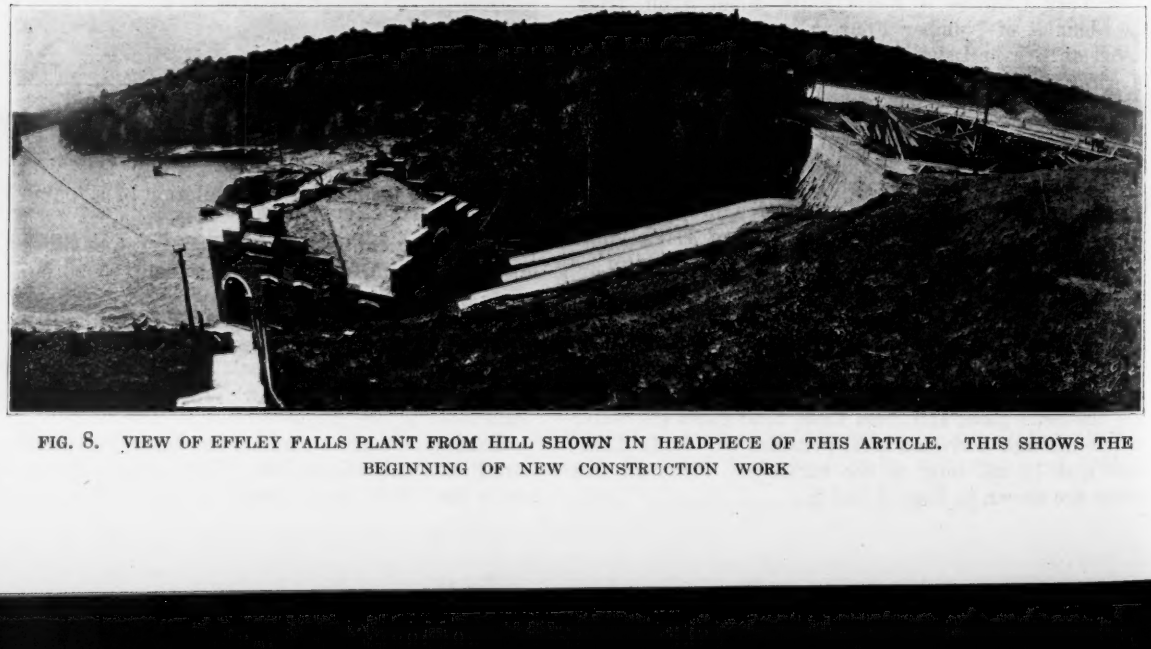


FIG. 8. VIEW OF EFFLEY FALLS PLANT FROM HILL SHOWN IN HEADPIECE OF THIS ARTICLE. THIS SHOWS THE BEGINNING OF NEW CONSTRUCTION WORK

Elmer Falls, situated about 1 mi. south of Effley Falls and 8 mi. from the town of Croghan, is a small modern development. A concrete, gravity type dam 300 ft. long and 32 ft. high gives a pond of 19 acres and a head of 37 ft., which is utilized by a plant at the southerly end of the dam. In the concrete power house are two vertical turbines manufactured by the Hydraulic Turbine Corp. of 1220 hp. each, at 257 r.p.m. The turbines are governed by Woodward type H.R. 8¾ by 12-in., 10,000-ft.-lb. governors and are direct connected to General Electric generators of 2300 v. and 235 amp., at 80 per cent power factor. These generators are excited by separate General Electric exciters which are arranged in duplicate, one exciter being sufficient for both generators. The current generated is stepped up to 22,000 v. for transmission by General Electric transformers. The drainage area at this development is but little larger than at Effley Falls and the flow will be

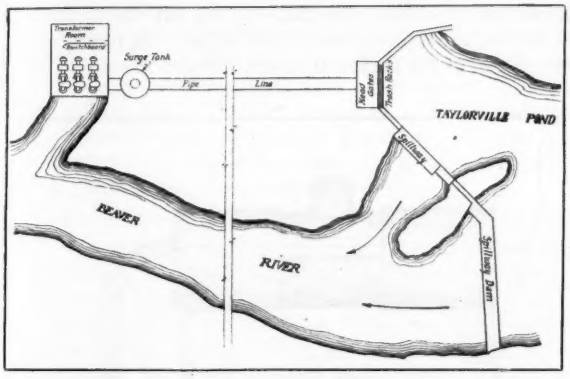


FIG. 9. THE ARRANGEMENT AT TAYLORVILLE

about the same but slightly retarded. The tailwater at Effley Falls is directly discharged into the Elmer Falls pond and the Elmer Falls plant in turn discharges its water directly into the Taylorville pond.

About 1 mi. east of Bellfort and 4½ mi. from Croghan, is located the Taylorville plant. This plant, built in 1913, is situated on the northerly bank of the Beaver River, as shown in Fig. 9, which at this point has a drainage area of about 257 sq. mi. The hydraulic works consist of a dam built in two sections; the first, being the spillway, is a concrete gravity type dam about 1100 ft. long and 20 ft. high, the other section which is at the northerly end contains some additional spillway, a log chute and the head works.

In the power house (Fig. 10) which is built of concrete block upon a concrete sub-structure, are three S. Morgan Smith horizontal turbines set in cast-iron spiral casings and designed to produce 1800 hp. under 107 ft. head and at 450 r.p.m. These turbines, shown in Fig. 11, are equipped with Gibbs end thrust bearings and are governed by special Lombard governors. The alternators with direct connected exciters are General Electric machines of 1100 kw., 80 per cent power factor, 2300 v. and 345 amp. The current is stepped up to 22,000 v. for transmission by General Electric transformers.

At the present time, extensive electrical alterations are under way at this plant. It is the plan of the company to make it the distributing point for all the plants on the Beaver River; the transmission lines from the various plants will center here and it is from this station that the 22,000-v. line to Watertown and the 66,000-v. line to Utica will run. The tail race of the Taylorville plant discharges directly into the pond of the

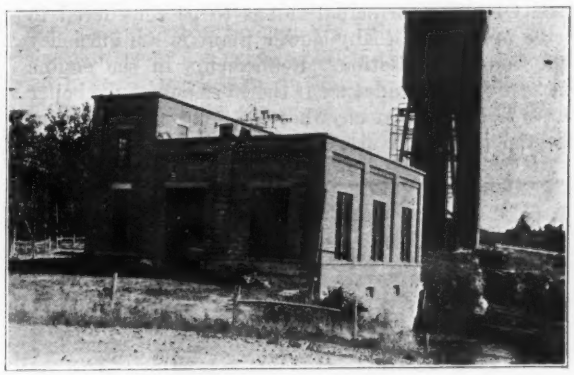


FIG. 10. TAYLORVILLE POWER HOUSE SHOWING SURGE TANK IN REAR

old Bellfort plant, which is about 35 acres in extent. The Bellfort plant, situated in the town of Bellfort, consists of a concrete dam founded on a ledge of solid rock which diverts the water into the head race. The water is led from this head race through two riveted steel penstocks to three horizontal turbines in cylindrical cases. These turbines were manufactured by the Camden Water Wheel Co. to replace the old cylinder gate wheels which were discarded as out of date several years ago, and are set in S. Morgan Smith cases. Two are twin wheel and the third a single one. All turn at 400 r.p.m. The electrical equipment consists of two 400 and one 1000-kw. General Electric generators which generate the electricity at 2300 v. This current is stepped up and fed into the Watertown transmission line.

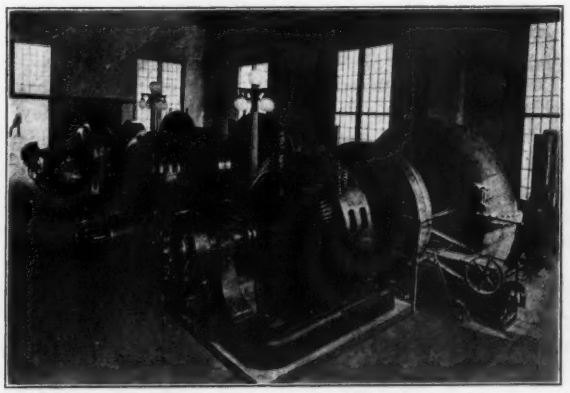


FIG. 11. INTERIOR VIEW OF POWER HOUSE AT TAYLORVILLE

These five plants, together with the one project, constitute the Beaver River System of the Northern New York Utilities, Inc. When the alterations and construction are completed and if the various reservoirs proposed by the New York State Commission are built, the stream will have a regulated flow of nearly 500 sec.-ft. continuous, all of which the plants of this company will use to the maximum advantage in its fall of 503 ft.

Building Up Efficiency in Small Boiler Plants

HIGH PRICES OF FUEL NECESSITATE MORE CAREFUL OPERATION OF SMALL AND MEDIUM SIZE PLANTS. BY R. C. DEMARY

ONE OF THE principal things to be considered in the operation of any power plant is the efficiency of the boiler installation. Refinements in the engine room have little significance if the efficiency of the boiler plant is maintained at anywhere from 10 to 15 per cent below the possible average. In spite of this fact, the

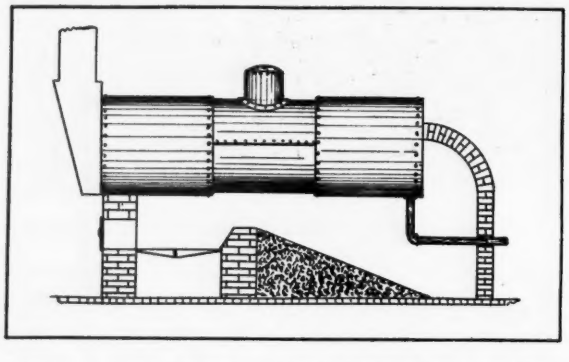


FIG. 1. LOW SETTING. SMALL COMBUSTION SPACE

percentage of small or medium sized plants, that is, those plants under 1000 boiler horsepower, which are operated without any pretense at efficiency is alarmingly large.

In a large industrial city the writer has completed a careful survey of over one hundred plants averaging from 50 to 1000 boiler horsepower all of which were hand fired. In most cases stationary grates were in use while in others shaking grates or some popular type of so called hand stoker was the choice. In only one case were the boilers equipped with draft gages and in not a single case was there any means of determining or obtaining a CO_2 reading. Twelve plants visited were equipped with one boiler only and in no instance was other power available, should an accident occur to the boiler or engine.

Tests were conducted in a number of those plants considered the most efficient and the highest efficiency obtained was 47 per cent. The reader may think this to be a situation peculiar to the locality but such is not the case. At least 70 per cent of the smaller power plants in this country are being operated in such a wasteful manner as to be alarming.

We have continued to draw on our nation's greatest resource until today our best and most valuable coal deposits are nearly exhausted and we are turning to seams less available and less desirable. The percentage of slate and other refuse in commercial coal has grown almost beyond belief in recent years and will continue to grow in the future. The era of low grade fuel is with us and we must now prepare for its further use by the development of furnaces and methods best adapted to the burning of such fuel in an economic manner.

What would be a modern and economic or efficient plant under certain conditions would not be so under other conditions. Every kind of coal from the graphitic anthracite of Rhode Island to the lowest grade lignites of the Northwest is now being burned for the production of power in the United States.

We have already learned that the so called "long haul" is wrong from an economical standpoint and the near future may see it prohibited by the Interstate Commerce Commission. This will mean that plants will be obliged to burn that fuel which can be obtained in their district.

In order that we may have efficiency we must first have dependability. We must operate without shutdowns. The boilers must be kept in condition—free from scale, soot, leaky baffles and leaky side walls. We must also use better judgment in the selection of boiler units. There seems to be a growing tendency to large single units. This allows for no flexibility. There should always be more than one boiler unit and those units should be of such size that cutting out one of them for cleaning or repairs would not impair the operation of the plant at its maximum load. There should be at

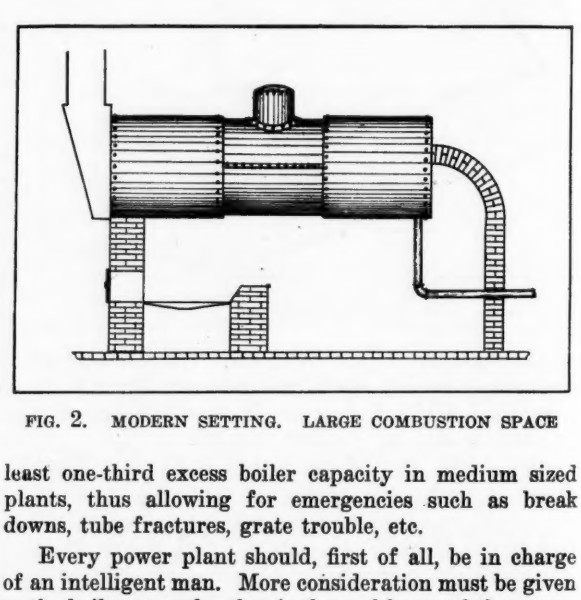


FIG. 2. MODERN SETTING. LARGE COMBUSTION SPACE

least one-third excess boiler capacity in medium sized plants, thus allowing for emergencies such as break downs, tube fractures, grate trouble, etc.

Every power plant should, first of all, be in charge of an intelligent man. More consideration must be given to the boiler room for that is the real heart of the power plant and the vital part of nearly all our industries.

BOILER SETTINGS

More fuel is wasted because of improperly designed boiler settings than is realized. Approximately one-half of the fuel must be burned in the combustion space, the balance burned to gas in the fuel bed itself. The passage of the valuable gases from the fuel to that part of the boiler or furnace where the temperature is too low to support combustion (about 1000 F.), takes only a fraction of a second.

During the travel of the gases at such high speed the minute particles of tar in these gases must absorb sufficient heat to become vaporized into a gas (methane CH_4), and the CO and soot which forms at the fuel bed must all unite thoroughly with sufficient oxygen to be consumed. This explains why low boiler settings cannot be operated with economy and without smoke. At the higher rates of combustion and with the high volatile

coals, these conditions become worse. The boiler setting with its stoker, or grates and other devices should perform functions as follows: It should have sufficient volume to give the combustible gases time to mix properly with the air admitted for combustion; it should be large enough to develop many times the nominal boiler horsepower. If necessary, as it is in some cases, wing walls, piers, or arches should be constructed so as to restrict the passage of the gases and assist in mixing them with the air admitted.

Figure 1 shows the setting of the average tubular boiler. Note the low setting and the restricted combustion space. This setting has been the standard for many years and even today the low setting is being used by those who are not abreast of the times.

In Fig. 2 is shown a modern setting, one that is economical in fuel, efficient and practically smokeless when fired with any degree of intelligence.

Until recent years, there was little use to economize on fuel or make an attempt to secure high rates of combustion. No consideration was given to furnace design. Conditions have changed; fuel prices advanced to such an extent that it became necessary to make a study of the conditions and determine a remedy. It was found that grate area and combustion space, in practically all cases, was too small for efficient combustion.

Experiments conducted by the Bureau of Mines brought out clearly that different coals required different sizes of combustion space. The higher volatile coals require a larger combustion space, excess air and rate of combustion being the same. The area of the combustion chamber, however, does not increase in direct proportion to the volatile matter in the coal.

Where the volatile matter distilled off is doubled per unit of time, the excess air and completeness of combustion being the same, the combustion space need not be increased more than 25 per cent. The accompanying table, prepared by the Bureau of Mines, shows the influence on furnace volume.

Regardless of that part of the country in which the boiler may be located, or what kind of bituminous coal may be used, or whatever the combustion rate or boiler load may be, a high setting should be provided. The extra coat of brick work is a small item in comparison to the return secured.

Boiler Room Instruments

Boiler room instruments must be selected carefully. The cost of a complete set of boiler room instruments for the small plant is almost prohibitive and there is a question as to whether there would be sufficient saving to warrant their purchase.

Each plant should, however, be equipped with a draft gage for each boiler and have some means of determining the CO_2 percentage. Recording instruments are expensive and would not get the required attention. Reliable draft gages and portable, or so called "pocket CO_2 instruments" can be purchased for a nominal sum and their use will pay for themselves many times during the year.

A simple draft gage will indicate the difference in pressure between the point where it is connected and the atmosphere. A differential gage, which costs but little more, will indicate the difference in pressure between two points in the gas passages. Efficient combustion requires a certain amount of air for each pound of fuel burned. When combustion is taking place properly the quantity of gases will be in direct proportion to the boiler load. The boiler offers a constant resistance to the passage of these gases. A differential gage will indicate the pressure drop through the boiler and thus act as a gas flow meter, showing whether the proper amount of air is being supplied for the load carried. A differential gage will also show the pressure drop through the fuel bed, indicating any change in the fuel conditions. An increase in the fuel bed drop will indicate that the fuel bed is becoming thicker or that the fires are dirty and should be cleaned. When the pressure drop decreases it indicates too thin a fuel bed or holes in the fire.

In all cases, a good damper should be a part of the necessary equipment. It should be so connected that the control will be at the front of the boiler or where it is most convenient for the fireman to operate and at the same time watch the draft gage. Use a high draft with high rates of combustion and a low draft with low rates of combustion. Frequently a high draft is used for low rates of combustion; as much as 40 to 50 lb. of air being used when 15 lb. would be sufficient. Change the position of the damper slowly and regulate draft entirely by it and never by the ash pit doors, as the latter method has extremely bad effects. It shuts off the air supply through the fuel bed, the ash on the grates becomes heated, and burned grates and clinkers result. The draft intensity is increased and air is drawn into the furnace through leaks in the setting and around the fire doors, out of all proportion to the amount required.

SIZE OF COMBUSTION SPACE REQUIRED FOR THREE COALS

Size Of Combustion Space Required For Three Coals.					
Completeness of Combustion per cent of undeveloped heat.	Combustion Rate per Sq. Ft. Per Hr.	Excess Air per Cent.	Cubic Ft. Combustion Space Per Sq. Ft. of Grate.		
			Pocoh.	Pitts'gh	Ills.
5.0	50	50	2.7	2.9	4.3
3.0	50	50	3.2	3.7	5.3
2.0	50	50	3.6	4.4	6.3
1.0	50	50	4.0	5.6	8.9
0.5	50	50	4.8	6.8	11.9

We will now assume that we have the coal best adapted to our plant. The problem which now confronts us is how best to burn this fuel. In other words, how can we get the most heat into the boiler and thereby produce the greatest amount of steam per pound of coal fired.

We know that certain coals require a certain amount of air for complete combustion. This theoretical amount of air, however, will not be sufficient, owing to peculiar condition existing in the furnace. Consequently an excess amount of air must be supplied in order to make our combustion as complete as possible. Too much excess air is just as detrimental as too little. To make this determination, we must make an analysis and determine the amount of CO_2 or Carbon Dioxide. As previously stated a "pocket" instrument giving us the CO_2 determination only is sufficient for the small plant.

To obtain a suitable reading, we must first locate the approximate center of the gas flow. This is the place where we get the highest CO_2 percentage with the greatest fluctuation. After obtaining a suitable reading

we can easily determine the amount of excess air flowing through the furnace and boiler passes. Without making a complete analysis, we cannot determine the exact amount of excess air; but we can make a determination which will answer our purpose. This is done as follows: Subtract the percentage of CO_2 observed from 20.7, divide the remainder by the observed CO_2 and multiply by 100.

Air normally contains 20.7 oxygen by volume. The carbon unites with the oxygen forming CO_2—that is one part carbon (C) and two parts oxygen (O_2). We can now see why the lower CO_2 we obtain the greater will be our fuel loss. Roughly there is 1 per cent fuel loss for every 12 per cent of excess air above 38 per cent.

As an illustration, suppose we find our CO_2 percentage to be 5, which is not uncommon; it will mean that we have 314 per cent excess air and roughly our preventable fuel loss would be 22.79 per cent. Our 5 per cent CO_2 means that we are heating 314 per cent excess air and that we are wasting practically one-quarter of our fuel. For every 100 cu. ft. of air used in burning our coal we are taking in 314 cu. ft. additional which we must heat to the temperature of the uptake gases.

We must now determine where this excess air is coming from. Our draft gage shows a decrease in draft. We examine the fire and find several holes. These are covered, the fuel bed leveled and we notice our draft has increased. We now take another CO_2 reading and obtain 8 per cent. Substituting this figure for that in the previous case, we find our excess air to be only 158.7 and our preventable fuel loss has been reduced 9.66 per cent which means considerable even in a small plant. We increase the thickness of our fire but find that 8 per cent CO_2 is the best we can obtain. We go over the boiler setting carefully and discover a number of air leaks and proceed to stop them. After so doing, we discover that we have increased our CO_2 to perhaps 12 per cent which means only 72.5 per cent excess air and a fuel loss of only 2.84 per cent. Knowing that we have all leaks closed it is just a question of study until we find that condition of fuel thickness and draft which will give us from 12 to 14 per cent CO_2. I would not advise trying to go higher, but would be satisfied with the amount mentioned.

All instruments mentioned in this article can be purchased at a very small cost and my advice to the engineer in charge of the small and medium sized plant is to try and secure them, for there is no question but that they will pay for themselves several times during the year.

Methods Used in Calculating Tank Volumes

SOME PROBLEMS ARE QUITE SIMPLE, SOME REQUIRE THE AID OF CALCULUS, AND SOME CAN BEST BE SOLVED BY PRACTICAL METHODS. BY J. H. POUND*

MANY liquids used about power plants and in the industries require periodic measurement while resting in storage tanks. Often the containers are of such a shape that the calculations involved are quite simple, but occasionally the process becomes so complicated as to call for considerable mathematical knowledge. Many operating men have never possessed that information, and others find it so rusty with disuse as to make the job a difficult one. Fortunately, many a tank problem which appears intricate at first glance can be reduced to simple cases by a little thought. The purpose of this article is to describe a number of fairly common problems and to suggest rather simple methods or equations for handling them. Since all of these solutions are adapted from pretty well-known geometrical equations, found in most engineering hand-books, no attempt is made to prove these relations. To do so would probably be both superfluous and distracting.

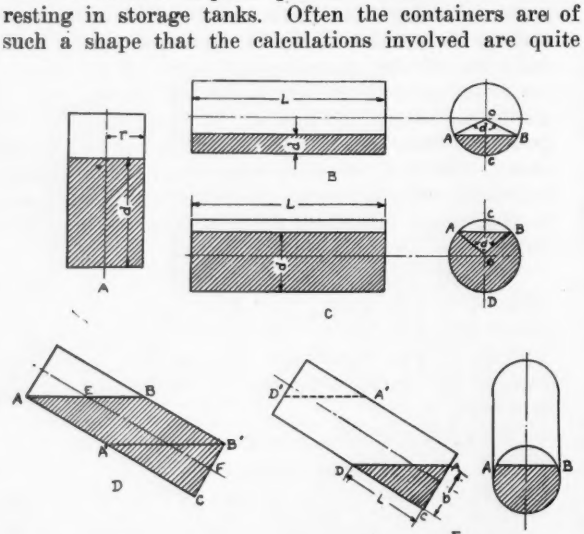


FIG. 1. CYLINDRICAL TANKS. A, VERTICAL; B, HORIZONTAL LESS THAN HALF FULL; C, HORIZONTAL MORE THAN HALF FULL; D AND E, INCLINED CYLINDRICAL TANKS

Many tanks are permanent structures. In such cases, one set of calculations can be used for years if carefully preserved. Sometimes the contents of tanks can be read directly by using some of the several ingenious float or pressure gages or by providing the man who does the reading with a sounding-rod graduated in units of volume rather than units of length. Depth readings can also be taken in feet and transformed into volumes by consulting either a table showing volumes computed for each inch of depth or else a curve plotted, depth against volume contained in the tank. This last method is especially good where the contents per inch of depth changes rapidly at some points, because it can be made to give greater accuracy than the table when the depth measurement contains fractions of an inch. In either case, it is well to make the computations for a given tank once and for all, and to record them in a permanent file which may be copied but not borrowed.

Probably the commonest tank is in the shape of a right circular cylinder (Fig. 1A). If its radius is represented by r, and the depth by d, the volume of the liquid is $3.1416r^2d$. This is easy enough; but the volume of liquid in a similar tank whose axis is not vertical is more difficult to calculate.

Take first the case of a horizontal cylinder, like a tank car, less than half full (Fig. 1B). The line AB

*Asst. Professor, mechanical engineering, Rice Institute.

shows the surface of the liquid. Its volume is, of course, the cross-sectioned area ABC times the length L of the cylinder. This area ABC can be found by a simple geometrical process in two steps. Area ABC is the area AOBC minus the area of unshaded triangle AOB. We can get these last two areas separately.

As before, let r equal the radius of the tank and d the depth of the liquid, both of which we can measure. Let a equal the angle AOB, which we do not know yet. Area AOBC = area of circle $\times$ angle a $\div$ 360 deg. To learn angle a, cut triangle AOB into two right triangles. From elementary trigonometry, we know that cos $(a \div 2) = (r - d) \div r$. Calculate cos $(a \div 2)$; find $(a \div 2)$ in a table of natural cosines; double it; and calculate area AOBC.

Areas of triangle AOB is half the altitude times base AB. The altitude is $r - d$; and since the small triangles are right triangles, $r^2 - (r - d)^2 = (AB)^2 \div 4$, from which AB can be calculated. Having found area AOB, get area ABC by subtraction, multiply it by L, and the job is done.

For example, suppose we have a tank 6 ft. in diameter by 10 ft. long, in which oil stands at a depth of 2 ft. 3 in. Cos $(a \div 2) = (r - d) \div r = (3.00 - 2.25) \div 3.00 = .75 \div 3.00 = .25$; therefore angle a = 151 deg., and area AOBC = $3.1416 \times 3^2 \times 151 \div 360 = 28.274 \times .4195 = 11.86$ sq. ft. $(AB)^2 \div 4 = 3^2 - .75^2 = 8.437$; therefore AB = $\sqrt{33.75} = 5.81$ ft. Area of triangle AOB = $.75 \times 5.81 \div 2 = 2.18$; therefore the area of section of the fluid is $11.86 - 2.18 = 9.68$ sq. ft., and the volume of oil in tank is 10×9.68 or 96.8 cu. ft.

Now assume the tank is more than half full (Fig. 1C). The volume is shaded area ABD times length L; and shaded area ABD is $3.1416r^2$ — area ABC. This area ABC can be found as shown above. Area ABD is also $3.1416r^2 \times (360° - a) \div 360 +$ area of triangle AOB.

If an engineer needs to gage a tank of this type frequently, he should calculate its volume for various depths and prepare a curve as shown in Fig. 2, from which volumes can be read off directly. In plotting such curves, an equation is probably easier to use than the successive steps just described. With the aid of calculus, we can prove that the cross-sectional area of the liquid in such a tank is given by the formula $(d - r)\sqrt{r^2 - (d - r)^2} + 3.1416\ r^2 \div 2 + 3.1416\ r^2 \div 180°$ (angle whose sin is $(d - r) \div r$. To illustrate its use, take the example given in connection with Fig. 2. For that case $(d - r) = -.75$, $r^2 = 9$, $(d - r)^2 = .5625$; therefore sectional area = $-.75\sqrt{8.4375} + 14.14 + 3.1416 \div 180 \times 9 \sin^{-1} - .75, \div 3$, or $-2.18 + 14.14 - 2.276 = 9.69$ sq. ft. This result checks the one previously secured. For the man who does not understand calculus and cannot derive this formula, the first method may prove desirable, because it is more easily remembered than the equation.

If the axis of a cylindrical tank is neither vertical nor horizontal, still different methods must be applied. If the liquid level lies on line AB or A′B′ (Fig. 1D) or anywhere between these two limits, that is, one head is completely covered while the other is dry—the liquid takes the shape of a truncated right cylinder. The volume of such a figure is the area of its base times its mean height, or 3.1416 r^2 times the distance EF. This mean height EF is, of course, $(BB' + AC) \div 2$. It would doubtless be easier to measure BB′ and AC and use this formula than actually to measure EF.

But if the liquid is as shown shaded in Fig. 1E, its shape is not cylindrical, and the above scheme will not work. This shape is known as an ungula, and its volume cannot be found by simple mathematics. It is, however, possible to prove that its volume is $L \div b\ (AB^3 \div 12 + bE - rE)$, where E represents the area of the head wetted by the liquid. Perhaps AB cannot be measured directly; but if r and b are known, both AB and area E can be computed by the methods shown for a horizontal cylinder.

In case the tank is almost full, with the liquid level at D′A′, Fig. 6, the volume of the unoccupied space above the liquid can be found by the formula just given, and this volume can be subtracted from 3.1416 r^2 L, the total volume of the cylinder.

In large cylindrical tanks, a certain number of internal braces and roof-supports is necessary. The volume

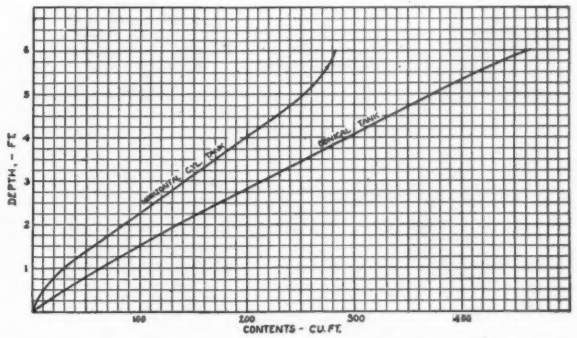


FIG. 2. CAPACITY DEPTH CURVES FOR CONICAL AND HORIZONTAL CYLINDRICAL TANKS

of this "dead wood" may have to be deducted from the gross volume of the tank by the man who "straps" or gages it. Fortunately, the dead wood is usually in the shape of cylinders or four-sided prisms, whose volumes are their cross-section times their mean length.

Another common shape, especially popular for wood-stave tanks, is the frustrum of a cone. (Fig. 3A.) Its volume is $d \div 3\ (B + b + \sqrt{B \times b})$, where B and b are the inside areas of the top and bottom of the liquid. This formula would also hold for any pyramidal tank or piece of "dead wood" (like the base of a column), and is correct even for a conical or pyramidal tank whose axis is not vertical, so long as the surfaces of top and bottom of the liquid are parallel and d is the perpendicular distance between them. If by distortion of the tank the upper and lower surfaces become ellipses instead of circles, and if a is half the greatest and b is half the shortest dimensions of the ellipse, the area of the surface is given by the formula, area = 3.1416 ab. For tanks shaped like the frustrum of a right circular cone (Fig. 3A), the formula for volume can be made easier to handle by writing it $3.1416\ d \div 3\ (R^2 + Rr + r^2)$, where R and r are radii of bottom and top surfaces of the liquid.

As an example, assume a conical wood-stave tank which is 6 ft. deep and whose inside diameters are 8 and 10 ft. at top and bottom. Suppose water stands in it at a depth of 3 ft. 7 in., or 3.583 ft. The radius at the top of the water can be found by similar triangles

(Fig. 3A) to be $r = r' + d \div h\ (R - r')$, where r' is the inside radius of the top of the tank. For this particular tank and depth, $r = 4 + 3.583 \div 6\ (5 - 4) = 4.597$ ft.; therefore volume $= 3.1416 \times 3.583 \div 3\ (5^2 + 5 \times 4.597 + 21.13) = 259.25$ cu. ft.

In plotting the capacity curve for this tank, the above method can be turned into one formula by combining the equations for r and for volume into one expression in terms of d. This avoids the necessity for calculating r. For example, if we use the tank dimensions assumed above, $r = 4 + d \div 6\ (5 - 4) = 4 + d \div 6$. Substituting this in the volume equation, we have volume $= 3.1416\ d \div 3\ [25 + 5\ (4 + d \div 6) + (4 + d \div 6)^2] = 3.1416\ d \div 3\ (61 + 2d + d^2 \div 36) = d\ (63.879 + 2.094d + .0291d^2)$, for a tank of these dimensions. Substituting various values of d will permit us to plot the curve in Fig. 2 for conical tanks.

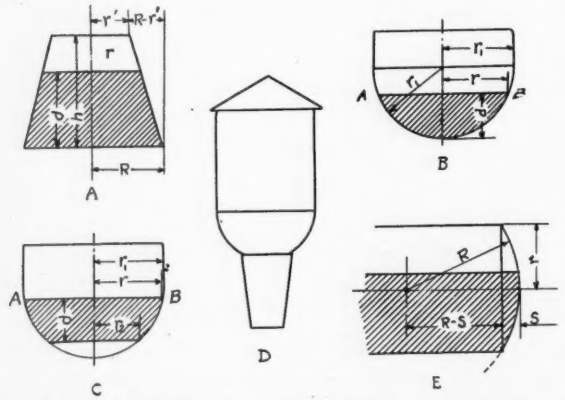


FIG. 3. MISCELLANEOUS SHAPED TANKS; A, CONICAL; B, SPHERICAL BOTTOM; C, SPHERICAL BOTTOM WITH ZONE MISSING; D, COMPOSITE TANK, CYLINDRICAL, SPHERICAL AND CONICAL SHAPES; E, HORIZONTAL CYLINDRICAL TANKS WITH CONVEX HEAD

Sometimes inverted cones are met, as in the agitators for oil refining and in the outlets of some tanks. The same volume formula applies whether the large base is below or above the smaller one.

Reservoirs for water are often made with a hemispherical bottom. The amount of fluid in this part of the tank (Fig. 3B) can be gotten from the formula, volume $= 3.14\ d \div 6\ (3r^2 + d^2)$. It is not necessary to measure r, because $r_1^2 = r^2 + (r_1 - d)^2$. But if the hemispherical bottom ends in a flat plate or a large outlet, so that the bottom is only a zone cut from a sphere as in Fig. 3C, then the volume is $3.14\ d \div 6\ (3r^2 + 3r_2^2 + d^2)$.

Figure 3D shows a shape of tank often met. To calculate its volume-depth curve would require the use of equations for a right circular cylinder, for the zone of a sphere, and for the frustrum of a right circular cone.

In discussing horizontal cylindrical tanks, only those with flat ends at right angles to their sides were mentioned; however, many cylindrical tanks have dished or bumped ends. If one head is concave, the other one convex, and both have the same curvature (a shape often used for small tanks, like air-drums), then the two heads can be considered the equivalent of plane ends, and the volume can be calculated by the method shown for flat ended cylinders; but many containers, such as boiler drums, tank cars and oil stills, are built with both ends convex outward. If they are full or half full, and the ends are segments of spheres (Fig. 3E), the contents of the cylindrical part can be calculated, and the contents of the spherical ends (which are figured just as for the tank with hemispherical bottom) can be added to it. To get the radius of the spherical end—a dimension which often is not the radius of the cylinder—use the relation $R^2 = r^2 + (R - s)^2$ or $R = (r^2 + s^2) \div 27$. Dimensions r and s must, of course, be obtained from the inside of the tank.

When the tank is neither full nor half full, this scheme is worthless. It is true that approximate formulas can be secured and it is also true that when the problem is attacked with the aid of calculus, a formula giving the exact volume at different depths can be secured; but it is far from being a simple one. The case of a horizontal boiler with a steam dome or of a tank car with an expansion dome is also complicated. Openings for clean-outs and manholes also do their part in making calculations difficult. It is entirely possible for situations to develop which can be solved more quickly by practical methods than by mathematics. A case of this character arose lately in connection with a boiler test. The water-level in the boiler drum not being the same at the start and the stop of the test, an engineer attempted to calculate the necessary correction for the weight of water fed the boiler. Not only were the ends of the drum convex, but the axis of the drum was not horizontal. After some hours of fruitless mental distress, he discarded his integral tables, filled the drum with water and gradually drew the water out into barrels mounted on scales, where it was weighed. This method of calibrating tanks is one which may be used by men with the simplest sort of education; and although in many cases mathematical methods are certainly great labor savers, in other circumstances calibration with a fluid like water is really the most efficient and accurate method possible.

Furnace Arrangement for Burning Fuel Oil

By Claude C. Brown

DETAILS of the air spacing in an oil burning furnace for one of the three burners in a 670-hp. Babcock and Wilcox boiler as adopted as standard for the installations of a western power company is shown in the accompanying sketch. The furnace is divided into three sections, each being arranged as shown and accommodating one oil burner. The ashpit under each section is individual to that section, being separated from the other two by 8-in. brick walls, built from the ashpit floor up to the under side of the furnace floor.

As shown, the furnace arrangement consists of wing-walls or piers which are built back against the boiler bridge wall and extend about 12 in. above the furnace floor. These wing walls serve the double purpose of properly diverting the burner flame, preventing the formation of eddy and counter air currents and of assisting in producing complete combustion, due to the fact that they become incandescent and heat the air that is mixed with the oil vapor issuing from the burner.

The oil burner, which is of the "rear shot" type, is introduced into the furnace from the front, through the ashpit door, extends back through the ashpit, where it is supported upon two pipe rests, and finally angles up through the 4½ by 24-in. opening at the back of the furnace with its tip facing forward.

The floor of the furnace consists of a 4-in. thickness of fire brick arranged in checker-work form as shown, the arrangement being in the form of a fan with an apex at the burner tip. This furnace floor instead of being supported upon grate bars, is supported upon a row of 4-in. I-beams that are laid crosswise at intervals for the support of the bricks and which are in turn supported by the two ashpit separating walls and the side walls of the boiler setting. The resulting free area in this arrangement is as follows.

Free area through checkerwork	1500 sq. in.
Free area around burner	432 sq. in.
Total free area	1932 sq. in.
Free area per boiler hp.	2.81 sq. in.

This amount of free area for air distribution has been found to be sufficient for a continuous operating rating of 250 per cent.

The burners used with this furnace, as shown in the sketch, consist of a ¼-in. oil line surrounded by a 1-in. steam line. The oil pipe extends from the control end of the burner, surrounded by the atomizing steam to the elbow of the burner, up the short vertical portion, and terminates as the support to which the cap of the burner tip is screwed. The fuel oil, heated by the surrounding atomizing steam, is finally deposited into the oil portion of the burner tip, through the four 1/16-in. holes. The pressure of the fuel oil, which is maintained at 50 lb. per sq. in., forces the oil out through the 1/16-in. oil slot in a fan shaped film. Steam and oil are prevented from mixing in the burner tip by the ground joint shown in the sketch.

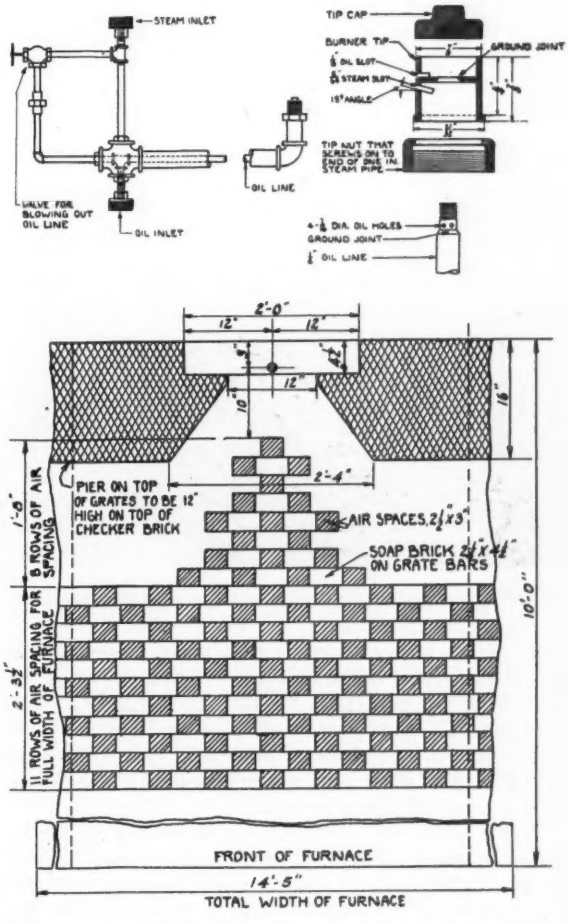
The atomizing steam, the pressure of which is 100 lb. per sq. in., is conducted to the steam portion of the burner tip and allowed to escape through the 5/64-in. steam slot in the tip. This slot which is tipped up toward the oil film at an angle of 15 deg. with the horizontal, also forms a fan shaped film upon which the film of oil rests.

Fuel oil and the steam form a fan shaped film of atomized vapor that is thrown out from the burner tip and spread over the furnace. The lighter portion of the fuel oil is consumed near the burner tip and over the narrowest part of the checkerwork, for this portion of the oil being light does not need as much air for complete combustion as the heavier portion. The heavier portion of the fuel oil is thrown far out toward the front of the furnace and over that portion of the furnace floor in which the greatest free area is laid. Thus the air for combustion is distributed as it should be and the result is that the fuel oil is completely and thoroughly consumed, resulting in practically smokeless combustion.

Widths of the oil and steam slots in the burner tips are so regulated as to cause the tip edges of each fan flame just to touch the tip edge of the flame adjacent to it. Should these tips overlap to any degree, smoking will result at these points.

Maximum efficiency of operation and the most complete combustion is attained when a minimum amount of steam is used for the atomization of the oil. The amount used should not exceed 1½ per cent of the total steam generated by the boiler. The steam used should be as dry as possible and preferably superheated. Utilization of wet steam for this purpose results in a sputtery and smoky flame and incomplete combustion.

Another requisite of good combustion is that the draft on the boiler furnace should not be greater than is absolutely necessary. For ordinary operation at 100 to 150 per cent rating, 0.10 to 0.15 in. of water should



FURNACE ARRANGEMENT AND DETAILS OF BURNER FOR OIL FIRED INSTALLATION

suffice. For overload conditions, a draft as high as 0.35 in. is necessary for the proper combustion of the larger quantity of fuel oil handled. All air that is used for the combustion of the fuel should be admitted from beneath the furnace floor and through the checker work.

THOSE PARTS of the boiler shell, flues or tubes which are covered by water and exposed to the gases or to radiation constitute the heating surface. Any surface exposed to steam on one side and gases on the other side is superheating surface. The A. S. M. E. Boiler Testing Committee recommends that the heating surface be measured on the side exposed to the gases.

Novel Application of Indirect Heating

Heating System for Large Conservatory Contains Many Features of Interest. By C. H. Thomas

ONE OF THE most important features of a large greenhouse is its heating plant. Because of the absolute necessity of keeping the temperature in a building of this type at the proper point, especially in zero weather, it is imperative that the heating system be as near 100 per cent reliable as it is possible to make it. As in any other type of plant, efficiency is of course also important, but reliability must under no condition be sacrificed for efficiency.

It is to be expected, therefore, that the heating plant of the large horticultural group on the estate of Longwood, Inc., at Longwood, Pa., is of a high degree of excellence and that it possesses many novel features. This

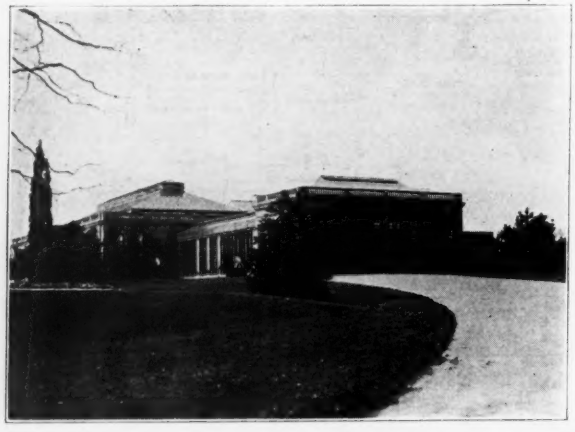


FIG. 1. ENTRANCE TO LONGWOOD CONSERVATORY

is one of the largest horticultural groups ever undertaken by a private estate and in the development of the engineering features, it is believed to include the first application of gravity indirect heating with complete equipment for temperature control. This system as applied to the main conservatory and the rose house will be described in this article.

This entire group of buildings represents an outlay of approximately $2,000,000—the boiler plant, heating and ventilating systems costing approximately $160,000 of this amount. The boiler plant is located under the terrace at the rear of the service building and is equipped with four 110-hp. Heine water tube boilers set in single battery 8 ft. 6 in. from floor to header with furnace designed for fuel oil.

In connection with the fuel oil installation an interesting feature is the construction of a 300,000-gal. reinforced concrete reservoir located underground and divided into two compartments, each having a capacity of 150,000 gal., the total being sufficient for approximately 14 mo. supply, allowing for a considerable increase to the present layout.

From the reservoir the underground oil supply line with heating pipe is run for a distance of 400 ft. to the service tank at the boiler house which is automatically filled. The oil burning equipment was furnished by the Hammel Co. and includes pumps, heaters, governors and temperature control for heating of oil in storage.

Steam is generated at the boiler plant at approximately 90 lb. gage, as all auxiliaries are steam driven units. Electrically driven units were not used, owing to the intermittent electric service which would endanger the life of the valuable plants housed in these buildings due to possible drop in temperature.

Steam is distributed to the various groups of buildings through reducing valves with remote pilot control. There are three distinct systems; that in the service building utilizes excess exhaust steam together with live steam which, when necessary, also heats the hot water for domestic service and the tempered water for the entire group; the next system of distribution supplies the typical greenhouse buildings known as the "Growing Group"; while the third system of distribution consists of an intermediate pressure main run through a

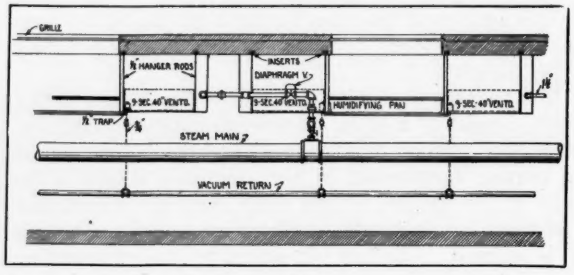


FIG. 2. SECTION SHOWING TYPICAL VENT CONNECTIONS

system of tunnels and underground to the main building where pressure is again reduced to low pressure. From this high pressure main a branch has been recently installed passing through the main building and underground for a distance of 1200 ft. to supply the garage, residence and vegetable greenhouse, thus eliminating the coal fired heating boilers at these points.

All sections of the institution are heated by steam with a vacuum system. The service building includes a large work-room, dining room, office and sleeping quarters in second floor and large storage for supplies in the basement. Automatic temperature control is supplied to all heated portions of the building except the bedrooms. Storage space is not heated. This building is approximately 70 by 60 ft. plus the wings having a floor area of 5200 sq. ft., the volume of the building being 90,000 cu. ft. with 6600 sq. ft. of wall surface, 2000 ft. of glass surface and approximately 1550 ft. of direct radiation to maintain average temperature of 70 deg.

Leading from the service building is a series of tunnels passing under the entire growing group and main building. In these tunnels are installed all heating, plumbing and electric distributing mains. The growing group adjoins the service building. These houses are of the typical greenhouse construction and have a total ground area of 22,000 sq. ft. with approximately 196,000 cu. ft. volume, 4800 sq. ft. brick wall surface, 36,600 sq. ft. of glass area. These buildings are equipped with approximately 7900 sq. ft. of direct radiation in the form of pipe coils supported on specially designed pedes-

tals and racks placed under the benches. The average temperature for this group is 60 deg.

Connected with this group is the rose house, which is equipped with indirect gravity system of heating similar to that applied to the main building. The main building is an imposing structure having a steel skeleton framework with glass roofs and large glass wall area. All steel work is encased in concrete treated with a special stone finish. It was particularly desired to eliminate the installation of visible direct radiation in this building which includes the orangerie, exhibition hall, peach houses and display houses with the organ loft and service room at the rear of the exhibition hall.

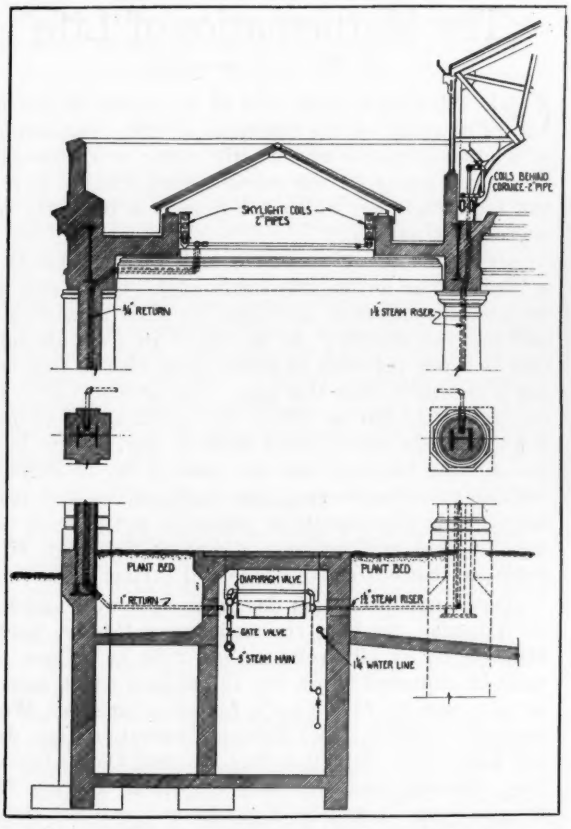


FIG. 3. DETAILS OF HEATING SYSTEM IN MAIN BUILDING

This is accomplished by the application of indirect system of heating provided with fresh air intakes and primary heaters to secure fresh air in moderate weather. The air is recirculated by means of floor grilles and provision is made to close the fresh air intake dampers automatically and open recirculating grilles. All the indirect heating stacks are located in a system of tunnels constructed under the walk-ways. The heating stacks consist of Vento cast-iron radiation divided into two banks located either side of the floor grille under which a dirt pan is placed. This construction may be seen in Fig. 2. All casing for indirect stacks and recirculating grilles is of sheet copper. The main building has a total floor area of 44,000 sq. ft. with a volume of 1,130,000 cu. ft., 20,000 sq. ft. of wall surface, 64,000 ft. of glass surface and is equipped with 12,000 ft. of radiation in tunnels, 3400 ft. of primary heaters at fresh air intakes and 8500 sq. ft. of concealed pipe coil radiation located in the cornice and around the skylights over the walk-ways. The system was designed to maintain an average temperature of 65 deg. in zero weather.

Thermostats Protected by Asbestos Lined Hoods

This system of heating was also applied to the rose house as previously stated. Owing to the difficulty of securing proper hand control for radiation which is located in the tunnels a complete system of automatic temperature control was installed. The thermostats were specially designed and consist of calibrated stem thermostats with the working parts mounted in cast bronze boxes with water-proof covers, the thermostat stems being protected with an asbestos lined copper hood to prevent action of sun effect. The thermostats are of two point control so arranged that one-half of the radiation would come into effect as the temperature falls to the room temperature desired. Should this amount of radiation not be sufficient, the second point

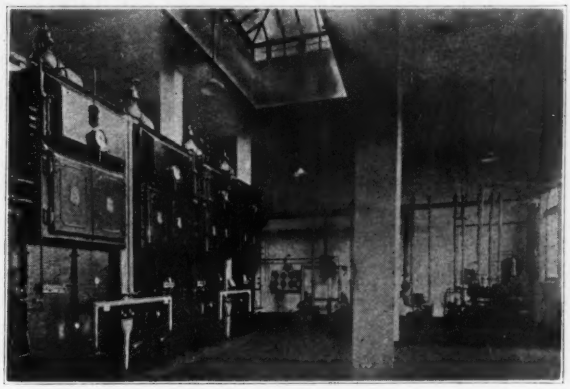


FIG. 4. BOILER ROOM AND PUMPS AT THE LONGWOOD CONSERVATORY

comes into effect and brings the second half of the radiation into service, the second units are equipped with intermediate acting valves. All coils in the skylight are concealed behind the cornice, as shown in Fig. 3, and are operated by thermostat control with diaphragm valves placed in the tunnels. In connection with the heating system it is found desirable to provide a system of humidifying pans consisting of copper coils submerged in water. Steam is admitted to the coils by group control through a diaphragm valve operated by means of room humidistat. This system is applied only to the orangerie, exhibition hall and organ loft sections of the main building. The humidifying system consists of 39 units with a capacity of humidifying 23,000 cu. ft. of air per minute at 65 deg. F. to 70 per cent relative humidity.

In order to supplement the ventilation in the orangerie and exhibition hall the ventilators in the skylight are operated by motor driven units with remote control from a central push button station, a total of 22 units. The sash can thus be quickly closed in an emergency.

In front of the main building under the terrace is a reception suite which is heated by a hot blast split duct system with automatic temperature control and bypass dampers. The system is equipped with a motor driven blower having a capacity of 3600 ft. per min. and with two propeller type exhaust fans each of 1600 cu. ft. capacity.

In the entire group of buildings there is contained approximately 18,000 sq. ft. of direct radiation, 12,000 sq. ft. of gravity indirect radiation, 3000 sq. ft. of primary coils at fresh air intakes, or an equivalent of 40,000 sq. ft. of direct radiation in the present buildings. The temperatures maintained in the various parts of the buildings range from 75 deg. maximum to 40 deg. minimum. The vacuum pumps in the boiler room con-

FIG. 5. INTERIOR OF CONSERVATORY SHOWING GRILL WORK IN FLOOR FOR PASSAGE OF WARM AIR

sist of two 8 by 10 by 12-in. steam driven units. These pumps together with the feed pumps, fuel oil pumps, and air pressures for the temperature control system, deliver exhaust steam into the feed water heater and all excess exhaust passes to the heating system of the service building. A separate low pressure steam driven vacuum pump is located at the rear of the main build-

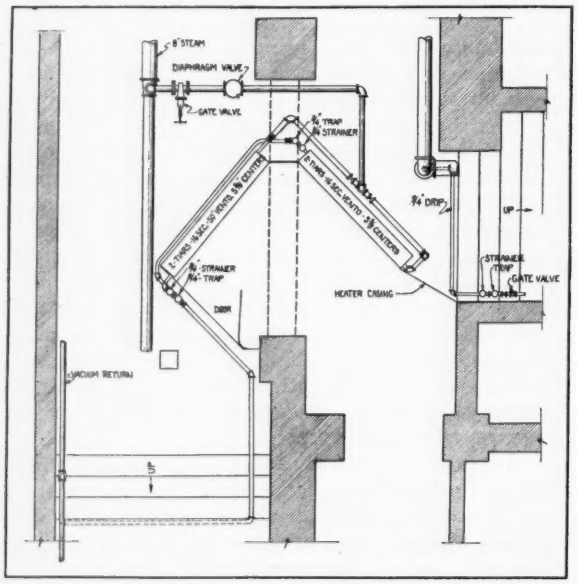


FIG. 6. DIAGRAM SHOWING TYPICAL PRIMARY HEATER CONNECTIONS

ing. This delivers the returns into an air separating tank and the water condensation returned to the feed water heater.

An interesting feature in connection with this work is the installation of a tempered water tank having a capacity of heating 5000 gal. of water per hour from 35 to 65 deg. F. It is used during the winter season when the water as received from the supply system would be too cold for use in connection with plant life; the cold water being heated to 60 or 65 deg.

Throughout the entire group the engineering details have been worked out to a nicety. Every precaution has been taken to conserve the heat and in many cases special types of coverings were required.

Robert P. Schoenijahn, consulting engineer of Wilmington, Del., had charge of the engineering features.

The Mathematics of Life*

By W. F. Schaphorst

ONE TROUBLE with most of us is that we are not fully aware of the shortness of life. Particularly is this true of people who are still young or who consider themselves young. I was startled when I looked at it in the following way, which I believe is a perfectly fair way of looking at it.

Up to the age of sixteen it may be excusable to be a "loafer" or to take life fairly easy. Up to that age we are inexperienced, our time has little money value, and we grow rapidly. At the age of 70, I am assuming that it is our privilege to retire if we wish so that loafing is excusable after that age. This gives us (70 — 16) 54 yr. of life during which we should spend at least 8 hr. seriously out of every working day. Eight hours are allotted to sleep and the other 8 hr. to dressing, walking or riding to and from work, eating, and recreation. It is also considered excusable not to work during Sundays and holidays including Saturday afternoons, so that our active life is still further curtailed.

On a basis of 8 hr. per day, 5 days per week and 4 hr. on Saturday, we have the well known "44-hr. week." Multiplying by 52 weeks, we get 2288 hr. From this must be deducted 96 hr. for 12 holidays which most of us take, namely, New Year's, Lincoln's birthday, Washington's birthday, Good Friday, Decoration Day, July 4th, Labor Day, Columbus Day, Election Day, Armistice Day, Thanksgiving Day and Christmas, leaving 2192 hr. per year. I will be generous and will not deduct any time for vacations, for sickness, or for special "off-days" taken by many of us.

Multiplying 2192 hr. per year by the 54 active yr., we get only 118,368 hr. as work hours.

In hours this may sound like a great deal, but divide it by 24 and one finds that it means only 4920 days, which divided by 365 shows that it is only 13.5 yr. In other words, we work only 13½ continuous years and are then satisfied to call it a "well rounded out life." Let us take a child 14 yr. old who will be trained to work 44 hr. per week and who will observe all the holidays and other trimmings. He has already lived longer before he begins to work than he will work during his whole lifetime after getting started.

Life is indeed short. It is unnecessary to ask a person who has lived through 70 yr.—these figures prove it. It is impossible to place too great a valuation on one's time.

*All rights reserved by author.

Prevention of Injuries in Construction Operations*

HAZARDS OF CONSTRUCTION WORK DIFFER FROM THOSE OF FACTORY WORK BECAUSE OF THE TEMPORARY CHARACTER OF THE WORK. BY J. A. P. CRISFIELD

IN SPEAKING OF "The Prevention of Personal Injuries," we are speaking of the result which we wish to produce. Injuries are prevented by the control or removal of hazards and it is with hazards that we have to deal. A hazard is anything which has possibilities of an accident connected with it in any way. An accident is an occurrence which is due neither to design nor negligence; negligence being culpable carelessness.

Accidents resulting from hazards are of two fundamental kinds. One is an occurrence which results in an injury where no human mental process was directly contributory to the hazard. A person may be walking along the street and get a cinder in the eye or be struck by lightning, or be hit by a broken trolley wire. A workman in a construction plant may step in a gully made by rain or slip on an icy walk.

Another class of accidents is the result of hazards to which the human mental process was contributory. In this class may be found by far the greater percentage of hazards. One authority states that 60 per cent of all accidents are directly the blame of the man hurt—10 per cent a fellow workman's fault—and only ½ per cent the employer's fault. A workman leaves a board with a nail sticking up and he or a fellow workman steps on it or he stacks bricks or steel so that the pile is insecure or walks too close to an excavation or drops a tool from an elevation.

HAZARD CONTROL

Hazards are removed or controlled in several ways:

By the careful supervision of employment and assignment of workmen; any physical examination of prospective workmen tends to reduce hazards. The proper assignment of workmen to jobs based on observations of their mentality, temperament and experience also tends to reduce hazard.

By the observation of the mental and physical condition of employes; workmen become careless through worry, become over fatigued, are handicapped by improper clothing or weakened through illness. All of these conditions tend to increase the liability of accident and when controlled tend to reduce hazards.

By the employment of specialists; the duties of these specialists are to study accidents and hazards and to remove or control them. Many organizations have a staff headed by a "Safety Engineer." It is his duty to see that stairs have hand rails, that projections on sidewalks are removed, that fire apparatus is always in order, etc.

By the education of employes in safety; many workmen are injured because they do not perceive or conceive a hazard. They would have no means of recognizing many hazards, unless taught by experience or by safety education. This is not necessarily a reflection upon the workmen's mentality. One not versed in safety matters would probably not realize that stairs are hazards. In one of the largest department stores of the country, there are nearly 100 accidents on their stairs to one in their elevators.

So many accidents happen because of some hazard to which the injured workman or a fellow workman is directly contributory, that it is evident that the education of workmen along safety lines should receive considerable attention.

The greatest difficulty in presenting the subject of safety or hazard control is to present it so as to avoid being obvious or monotonous. As an illustration, the signs reading "Avoid Fires—No Smoking," have no particular force or educational value. A sign reading, "If this building burns, you will be out of a job," has a "kick" in it and a real educational value.

Within many organizations, it will be found that there are many who show no particular interest or enthusiasm toward safety matters. The education along

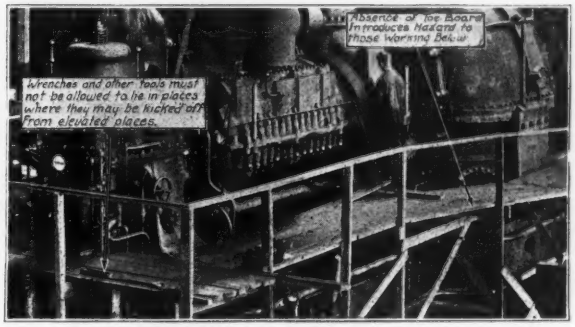

Absence of Toe Board Introduces Hazard to those Working Below
Wrenches and other tools must not be allowed to lie in places where they may be kicked off from elevated places.

FIG. 1. SCAFFOLDING SHOULD ALWAYS BE PROVIDED WITH TOE BOARDS TO PREVENT INJURY OF PERSONS WORKING BELOW

safety lines should not be confined to workmen, but all employes should receive a certain amount of training.

Although the presentation of safety matters to workmen is for the purpose of education, the method of presentation should be along practically the same lines as advertising. The psychology of safety presentation is the psychology of advertising. To the safety engineer or the employer, safety matters appear so serious that it is hard to believe that employes may be indifferent. For this reason, safety is not always brought to the attention of the employes in such a manner that there is created a desire to follow the suggestions made.

PRECAUTIONS TO BE OBSERVED

The prevention of injuries in construction starts with the design. Many hazards may be controlled or removed by proper design. This includes location of pipes above head height, the placing of valve stems away from passages, the construction of level floors, passes with ample space, and design of the machinery with sufficient working space around it.

One of the greatest hazards of construction work arises from the fact that practically a new organization is built for each job. For this reason more than ordinary care must be taken in the selection of workmen.

With common labor the lack of understanding of the English language is a serious hazard. Whereas established organizations, such as large manufacturing

* Abstract of a paper delivered at the 12th Annual Safety Congress, Buffalo, N. Y., Oct. 1-5, 1923.

concerns, can very well undertake the education of workmen, such a course is impossible on construction work. Workmen who cannot understand English should not be employed except as a last resort.

It is obvious that men should be assigned to jobs which fit in with their experience whenever possible. Dangerous hazards may be developed by assigning men to duties where they may be controlled by habits formed in other lines of work. For instance, workmen who have handled lumber for a long time are very liable to injure themselves in handling steel. Laborers who have been shoveling coke are very apt to strain themselves severely if assigned to shoveling sand. Many men cannot safely work above ground. To force a man who shows the slightest hesitancy to work at an elevation, is to introduce a serious hazard.

Many men habitually show a spirit of bravado toward hazards; these men should be weeded out of a construction organization unless they can be made to heed safety precautions. Men who prefer to slide down

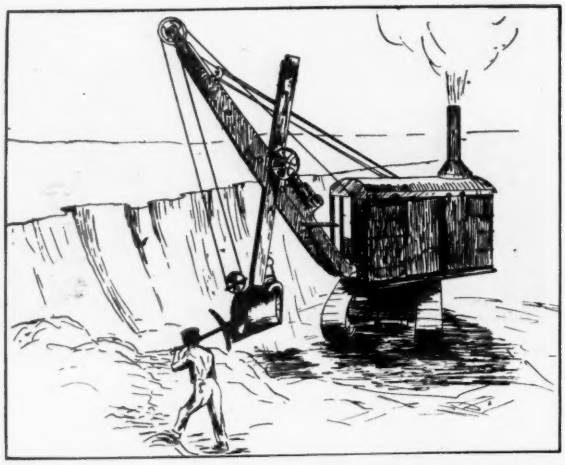


FIG. 2. A GREAT HAZARD RESULTS FROM WORKING IN CLOSE PROXIMITY TO SWINGING DIPPERS OR BUCKETS OF EXCAVATING MACHINERY

ropes rather than use ladders introduce a contagious spirit of recklessness. Men who continually turn to horse play or practical joking are dangerous. Men who habitually forget the ordinary precautions, as the use of goggles or the leaving of tools or material in dangerous positions, should be discharged if they cannot change their habits after being cautioned.

Preliminary Work on the Site

Fire and injury hazards are greatly reduced if an effective clearing of the site is made before construction starts. Loose boards, glass, boulders, etc., should be collected. Rubbish, grass, weeds, etc., should be burned. On large construction jobs the customer should be requested to construct as much of any projected permanent fence as is practical and general precautions against the trespass of the public should be undertaken. The nature of the ground should be determined and the shoring which will be necessary for the excavation should be on hand before work starts. As caving usually comes without warning, no chance should be taken. All the shoring which the experience of the engineer shows to be necessary should be used. Earth which will stand up when dry will often cave when wet. At night, all openings should be guarded by red lanterns and as many openings as possible protected by temporary fences or other guards, although they may not be so guarded in the day.

Handling of explosives should always be done by experienced men. The erecting engineer should question all men who are to be employed where explosives are to be used as to their previous experience and should give the foreman and workmen general instructions as to the methods to be followed, the precautions to be followed and the tools to be used. See that goggles and bar tongs are used when drilling is done by sledging. The handling of explosives should be under the direct supervision of a foreman blaster, known to be competent, self-reliant, trustworthy and conscientious, having good working knowledge of explosives. He should be physically fit and capable of performing any of the work under his direction. A man who boasts that he has handled dynamite for years and is not afraid of it, and handles it roughly to convince others that he has no fear of it, is a dangerous man to be engaged in this class of work.

Steam Shovels and Similar Excavators

A great hazard which arises from excavating machinery on construction work comes from the proximity of workmen to swinging dippers or buckets. Shovel trimming should be done when the excavator is at rest or on the side away from that on which the machine is working. There is a great tendency to rush work during excavation and to have men within the excavation too early. The hazard is considerably reduced if the excavating work is allowed to proceed without rushing the construction of forms too close behind the machinery. The location of concrete mixers is an engineering problem. Their location must be studied for efficient operation as well as safety. Proper location will also cut down the number of times which they will have to be moved with the attendant dangers of moving heavy awkward machinery.

Passages leading to and from mixers should be as straight as possible. Where such passages, as between mixer and sand pile, are not straight, the radius of the curve which the barrows will have to make should be large. Empty and full barrows should not be made to pass each other during operations except where there is ample space. All elevated walks and scaffolds on which barrows are to be pushed should have guard rails and toe boards. Ramps should be at low pitch and cleated.

Removal of Forms

Removal of forms is in a class with wrecking and is hazardous work. Men should be compelled to wear heavy-soled shoes and should be supplied with good gloves. The work should be undertaken in an orderly manner and always under the direct supervision of the foreman. The "slap-bang" method of dismantling is dangerous. It is no faster than an orderly method and is more destructive of material.

Placing of Steel Work

This class of work is extremely hazardous and only foremen known to be thoroughly experienced and careful should be employed. This employe should be part of the permanent organization of any company which is

erecting more than one plant and should be taken from job to job. He may then be thoroughly educated in the company's safety policy. None but experienced steel workers should be allowed to do any work on steel at an elevation.

Men should never be allowed to ride on derrick loads or slide down ropes. Rivet heaters should be assigned places and not be expected to work in odd corners. Scaffolds or platforms should be erected for them if necessary. Steel should be fastened before riveting with sufficient bolts to withstand wind pressure and standing loads. Ladders and scaffolds should be provided to eliminate as much climbing on steel as possible.

Welding

Gas tanks should be kept on the trucks which are provided. There are very few cases in which these trucks may not be transported to within working distance. When this is impossible, tanks should always be lashed to prevent their falling and the valves protected from falling material.

Pyrene type fire extinguishers should be considered a part of all equipment and be moved about whenever welding apparatus is moved.

Rigging

Rigging is an art that is acquired only by long schooling and experience. Many workmen, and in fact engineers, are inclined to think that because it looks easy anyone may do rigging. When rigging is done by inexperienced men it introduces very serious hazards.

Before work starts the rigging and tackle, if it has been used on previous jobs, should be thoroughly overhauled and inspected. Tackle which is not fit for use should be destroyed or otherwise disposed of so that workmen may not find it and use it.

All work of this class, no matter how insignificant, should be done under the supervision of riggers. Wherever derricks, lashings, ropes, guys or dead-men are to be used they should be installed by riggers.

Frequent inspection of all rigging should be made. Rigging which is subject to wear and tear should be inspected daily. It is poor economy to use rigging which has become worn. Riggers of the "Safety Last" class should be eliminated.

Ladders in general are so hazardous that they should be used only as an expedient. Ladders should be lashed in every case where they are in more or less permanent positions or when they are to be used by other workmen than those placing them. The use of rough ladders made from scrap material should be avoided. If ladders are to be constructed they should be made of the best material and with care and skill.

In any structure floors should be placed as soon as the erection has reached floor level. Temporary floorings should be used if necessary.

In plant construction, some of the greatest hazards are open hatches, wells and machinery foundations and pits. These are always numerous and should be guarded by railing and toe-boards whenever they occur along passages in the construction.

The placing of hoisting machinery is an engineering problem and when not taken care of in the design, must be given first thought by the erecting engineer. While they should be so placed as to provide for maximum efficiency, the hazard of their use should be borne in mind. They should not be placed close to passageways or highways. They should be so placed as to make it unnecessary for ropes to cross passages, etc. They should be in the care of persons whom the engineer knows to be careful and competent.

Guards should be provided for all moving parts. The operator should not be allowed to remove these guards and leave them off. Frequent inspection should be made for wear and torn parts should be replaced. This is particularly true of brake bands and clutch bands.

Electrically driven machines require good protection of the electric parts from both persons and the weather. The engineer should be sure that all fused and automatic cut-outs are always in proper running order.

All derricks, masts and booms should be erected and dismantled under the supervision of a rigger when hoisting operators are not in themselves experienced riggers. At the end of every shift all loads and strains should be removed from the hoisting machinery. Elevators should be grounded and booms should be grounded or "boomed-up."

In the installation of pipe work, it is of paramount importance that good tools be furnished and that they be kept in good condition at all times. Pipefitters are required to work under a strain in cramped and awkwark positions and at the tops of ladders or on temporary scaffolds. The slipping of wrenches is one of the worst hazards of pipe work.

Pipelifters should be furnished with enough good ladders so that they may reach any point of their jobs. Patent ladders which may be pulled into ladder scaffolds are of great use to pipefitters.

First Aid

On large jobs a dispensary should be erected as part of the executive office. A man skilled in first aid should be part of the force although his regular duties may be clerical or other work. Minor injuries may then be treated locally at a saving of expense and at the same time there will be treatment for injuries which otherwise might be neglected simply because they are of a character which does not warrant the calling of a doctor.

The equipment of the dispensary may consists of a standard first aid cabinet. These cabinets, completely equipped, may be purchased in nearly every locality. The equipment should include a stretcher.

Statistics show that about 65 per cent of the accidents on construction work arise from hand tools. These should be frequently inspected.

Pneumatic tools in the hands of inexperienced operators are particularly dangerous. Pneumatic tools must be only in the hands of properly instructed workmen.

As a general rule gasoline torches and melting pots should not be carried around or used promiscuously. Safe places should be selected for their use and they should be used in these places only. They should never be left burning without an attendant and should be extinguished when not in use. It increases the efficiency and decreases the hazard of such torches if asbestos screens are provided.

Tar kettles and the like should be placed only in carefully selected places. They should be placed on an incombustible base and be surrounded by sand. Sufficient sand to completely smother the contents of the pot should be at hand. Tar pots should never be heated at an elevation or inside any structure as it increases greatly the hazard of fire or asphyxiation.

Will It Pay to Burn Oil Instead of Coal?

By N. G. Near

THIS SIMPLE and handy chart will assist in deciding that question. To use the chart, it is merely necessary to zigzag across as indicated by the dotted lines and column G, which is pointed at by the arrow at the top, tells the number of B.t.u. there are to each ton of coal or gallon of oil purchased; that is, the same column G applies to both oil and coal.

In figuring the oil, begin at the left and zigzag toward the right to column G. In figuring coal, begin at the right and zigzag toward the left to column G. If the oil, for instance, contains 20,000 B.t.u. and the specific gravity is 0.9 and if the boiler efficiency with oil fuel is 80 per cent, the zigzag dotted line respective figures show that each cent will buy 24,000 B.tu.

Begin at the 5c, column A, and run through 80 per cent, column B, with a straight line. This locates the intersection with column C; from this intersection and 20,000 B.t.u. in column D locate intersection in column

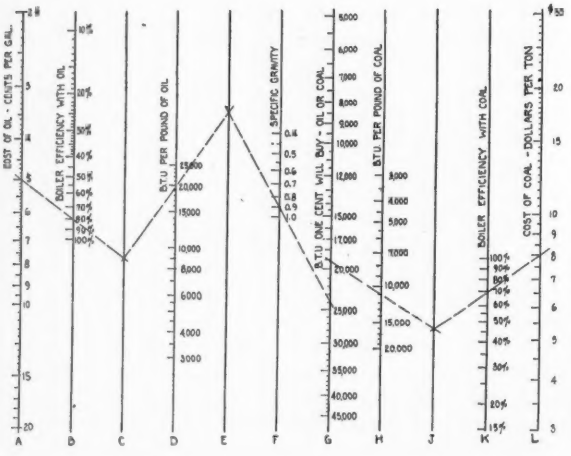


CHART FOR COMPARING COSTS OF COAL AND OIL

E; from this last intersection go through the 0.9 column F, and the final intersection with column G then gives us the answer—24,000 B.t.u. for each cent.

Now comparing with coal, we begin at the right. If coal costs $8 per ton of 2000 lb. and if the boiler efficiency using the same boiler as above is 70 per cent with coal and if each pound of coal contains 11,000 B.t.u. each cent will buy about 19,200 B.t.u. as shown in column G.

As will be noted, the $8 is found in column L, 70 per cent boiler efficiency is in column K. Run a straight line through both points and locate the intersection in column J; run a straight line through the 11,000 in column H and the intersection with column G gives us 19,200 B.t.u.

In other words, the solution of this problem indicates that the use of this oil at 5c per gallon will furnish nearly 5000 B.t.u. more for each cent than will coal at $8 a ton.

In using column A, the cost per gallon should include all costs—cost of hauling, cost of storing, etc.

It is well known that boiler efficiencies with oil are usually greater than with coal. The difference often is as much as 10 per cent, as in this problem where we use 80 per cent in column B and 70 per cent in column K.

Regarding specific gravity given in column F, an easy way in which to determine this is take any vessel such as a pail, jug, or bottle, and weigh it. Then fill it with water and weigh again. Subtracting the weight of the vessel gives us the weight of the water. Now do the same with oil and the exact weight of the oil by the weight of the water. The quotient is the specific gravity. The less delicate the scales used for weighing, the greater should be the size of the vessel. Where a sample of the oil is not available and where the density of the oil is given in degrees Baaumé, the accompanying table will be found useful in connection with column F.

Degrees Baumé	Specific Gravity
10	1.0
15	0.97
20	0.93
25	0.90
30	0.88
35	0.85
40	0.82
45	0.80
50	0.78
55	0.76
60	0.74
65	0.72
70	0.70
75	0.68
80	0.67
85	0.65
90	0.64
95	0.62
100	0.61

To calculate the specific gravity, knowing the degrees Baumé, simply add the degree Baumé to 130 and divide the sum into 140. The quotient is the specific gravity. As for the cost of coal, column L, this is similar to column A and must include all costs such as hauling, storing, pulverizing, and if purchased some time ago the interest on the purchase price.

This chart may be used in several ways for solving various problems. Thus by zigzagging clear across from left to right from column A to column L, knowing the cost of oil and all the necessary intermediate factors, column L gives the equivalent cost of coal. Or zigzagging toward the left from column L, we get the equivalent cost of oil. Thus with coal at $6 per T. and the boiler efficiency at 70 per cent we would find that a heat value of 10,300 B.t.u. per pound of coal would give us no advantage in using oil as regards cost of oil. But oil has other advantages such as greater simplicity, less labor required for firing, less storage space required, etc. All of these points, including particularly availability of supply, must be given consideration before one can decide that oil should be used in preference to coal, or vice versa.

THE FIRST and most important use for exhaust steam is to heat the feed water, since all of the heat of the exhaust steam so utilized is returned undiminished to the boilers.

Foreign Developments in Firing Pulverized Fuel

A General Discussion of the Use of Powdered Fuel with Particular Reference to British Practice. By C. H. S. Tupholme

IN THE BURNING of powdered coal, the various steps necessary in the preparation and utilization may be classified under the following headings: (1) Drying—where this is necessary. (2) Pulverizing. (3) Burning. (4) The removal of incombustible residue. These steps in the use of powdered fuel were recently discussed by J. S. Atkinson, of the Powdered Fuel Plant Co., at the Bradford Engineering Society in England.

Drying has been the cause of considerable controversy in discussions on powdered fuel. The removal of moisture in the fuel in the combustion chamber at a very high temperature has been considered unnecessary when it can be driven off at a moderately low temperature in a drier. On the other hand, the feasibility of drying coal in an inefficient drier when it can be done in an efficient furnace also has been questioned.

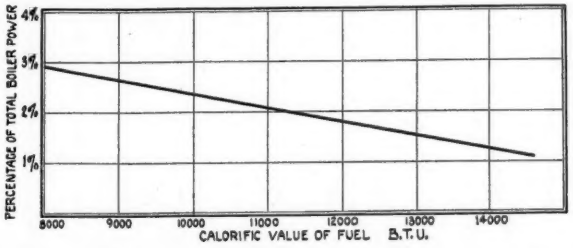


FIG. 1. PERCENTAGE OF BOILER POWER REQUIRED TO PREPARE POWDERED FUEL

Driers of many types have been designed, but the rotary drier seems to have been the one that has held its own. It is simple in construction, has a low maintenance cost, does not require much power, while its efficiency though low will compare favorably with other forms when all sides of the question are considered. The efficiency of the rotary drier varies from 50 to 70 per cent. The latter figure may be on the high side.

Those at present available include the direct and indirect-fired types. The power required for driving a rotary drier is small, as the shell rotates slowly, requiring about 2 hp. for a machine treating 2 T. per hr., 4 hp. for 6 T. per hr., 7 hp. and 10 hp. for treating 14 and 25 T. per hr. respectively.

Capacities and sizes of some American driers are as follows:

T. per hr.	Dimensions ft.	in.		ft.	in.
4	3	0	by	30	0
8	4	6	by	30	0
10	4	6	by	42	0
20	6	0	by	42	0
25	6	6	by	42	0

British practice demands driers of dimensions somewhat larger than these, owing to the higher moisture of British coals. American coals are usually much drier. When first trying to reduce the overall dimensions of a rotary drier, the Powdered Fuel Plant Co. developed a drier on a horizontal axis, making use of veins running in a helical manner along the shell. These veins were broken, and lifting plates were placed between them. In this way the coal was detained for a longer time in the drier-casing, and some advance was made towards a reduction of the overall dimensions.

There is now being studied another system of drying in which the drier is much smaller than any of those referred to in the foregoing. The proposal is to make use of sensible heat from the boiler combustion chamber as the drying agent. Gases will be taken from the chamber, diluted with atmospheric air, until the

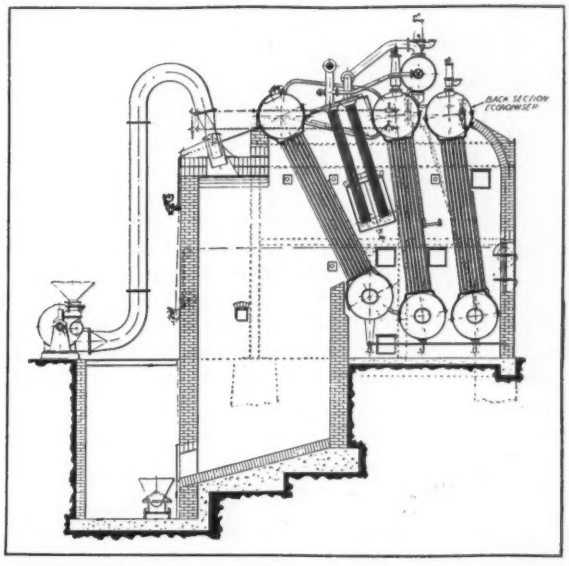


FIG. 2. TURBO-PULVERIZER FIRING A WOODESON BOILER

resulting temperature is below the flash-point of the coal, but much higher than current drying practice, and passed through a rotary drier of restricted size. After the gases have functioned as a drying agent, they will be exhausted from the drier by means of a fan, and returned again to the combustion chamber, through, or near, the burner. In this way, high-temperature gases may be used for drying, thus reducing the time factor and the size of the drier, while any dust which is carried through, or any volatiles which are driven off from the coal, will be burned in the combustion chamber near, or at, the burner.

This, it is believed, is an entirely new departure in drying, and the invention has been covered by a provisional patent.

With regard to recent developments, the tendency is towards either the entire elimination of any form of drier or reducing the size of this apparatus to a minimum. There are many installations of unit pulverizers employing no driers at work in this country and in Europe.

Problems of pulverizing are closely connected with those of drying. There are several mills of the grinding type, the makers of which specify in almost every case that the drying should be carried out until not more than 1 per cent of moisture remains. The same remark applies to ball and tube mills. All the mills

are of the crushing or of the grinding type. Some of them rely upon finely-meshed screens in order to obtain the requisite degree of fineness. In the grinding operation, if the moisture contained in the coal is much above 1 per cent, the screens have a tendency to become clogged. The Bonnot mill has been known to deal with coal having a moisture content of 3 per cent, but it is doubtful whether the mill could deal with coal having a higher moisture content. This mill, of course, relies upon the crushing action, but does not make use of finely-meshed screens.

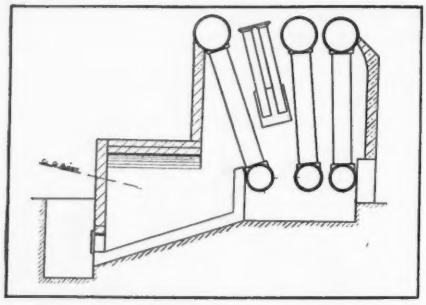


FIG. 3. INCORRECT DESIGN OF COMBUSTION CHAMBER FOR BURNING PULVERIZED COAL

Mills are usually driven by an electric motor by means of a belt, or silent chain-drive. The sizes of motors required for different capacities of three typical mills are as follows:

BONNOT MILL

2,500 lb. of coal per hour—25 hp.
5,000 lb. of coal per hour—50 hp.
10,000 lb. of coal per hour—75 hp.

To this power has to be added, for the air separator —7½ hp., 12 hp., and 25 hp. respectively.

FULLER MILL

2,500 lb. of coal per hour—20 hp.
5,000 lb. of coal per hour—35 hp.
10,000 lb. of coal per hour—50 hp.

STURTEVANT MILL

2,500 lb. of coal per hour—20-24 hp.
5,000 lb. of coal per hour—35-40 hp.
10,000 lb. of coal per hour— 45 hp.

In the latter case, a 12-hp. motor is required for the separator and a 10-hp. motor for the elevator.

Unit type pulverizers which the Powdered Fuel Co. developed in England and France have proved their usefulness, although, Mr. Atkinson said they had been working seriously on the problem since the latter part of 1919. There are 310 of the units in everyday use, and some remarkably efficient results have been obtained.

This pulverizer, which is called the turbo-pulverizer, is a mill of the true pulverizing, or impact type, as compared with the grinding mills referred to previously. The origin of the principle goes back about 40 yr. to an English inventor. In developing this machine, it was found that a number of further patents could be taken out, covering certain improvements.

This machine consists of an automatic feed, three or more pulverizing compartments, and a fan. Air is introduced at the feeding-end of the machine, and a further supply of what may be called "secondary" air, between the last pulverizing chamber and the fan. This air may be at atmospheric temperature or pre-heated. The turbo-pulverizer will take lumps of coal up to 1 in. in diameter and reduce them down to a very fine powder; it will deal with coal which is what may be termed "commercially" dry. At one installation a turbo-pulverizer has been in operation for some considerable time, and no attempt at drying the coal has been made. The coal arrives in barges, which are often leaky, and has been put through the turbo-pulverizer with up to 12 per cent of moisture with good results. Coal was 15 per cent of moisture has gone through the machine, but then the wear was rapid, and the horsepower necessary for pulverization was much increased.

Power required for a turbo-pulverizer when this machine is working at, or near, its normal capacity, or upon a slight overload, compares well with the power required by other mills, when it is considered that the machine supplies air for combustion at the same time that it pulverizes the fuel. Of course, the moisture content of the coal has a great effect upon the power required. The following powers may be given as examples with coals containing about 8 per cent of moisture:

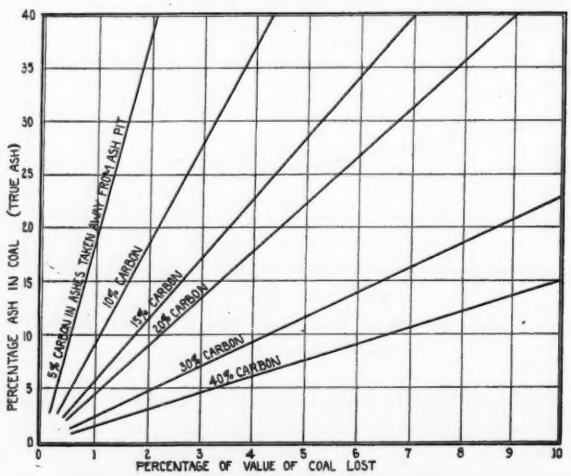


FIG. 4. LOSS IN HEATING VALUE OF COAL WITH DIFFERENT PERCENTAGES OF UNCONSUMED CARBON IN ASH

1100 lb. of coal per hour—14 hp.
1400 lb. of coal per hour—15½ hp.
2700 lb. of coal per hour—37 hp.

It will be noticed that the power required for 1400 lb. of coal per hour is, in proportion, on the low side when compared with the other two; but the explanation of this is that this reading was taken from a machine with a normal capacity of 1000 lb. of coal per hour, run on an overload, which is the most economical way of running these machines, in so far as the power required is concerned.

Recent figures relating to the fineness of pulverized coal have shown that a coarser pulverization than has been recommended by American practice gives as good results. Fine pulverization is undoubtedly, in theory, an advantage, but after we had reached a certain limit the gain is so infinitesimal that the greatly increased horsepower required by far outweighs any advantage. By means of a turbo-pulverizer with an extremely slight

modification, practically any degree of fineness can be obtained, but the fineness tests given in the following table show how the power required increases.

Output of coal per hour, lb.	Horse-power	Through 100 mesh screen, per cent	Through 200 mesh screen, per cent
1980	42.5	96	82
2700	37	94	75

Expressed in terms of 1000 lb. of coal per hour, the power required is 21.46 and 13.7 hp. respectively, for the outputs mentioned in the foregoing table. Although these figures are based upon an average of a number of tests, they cannot be looked upon as entirely representative, owing to the fact that moisture in the coal has a considerable effect upon the power required. If the coal will ignite quickly, burning with a minimum of excess air, say 15 per cent, and leave no trace of CO gas in the flue and no trace of unburned carbon in the ashes,

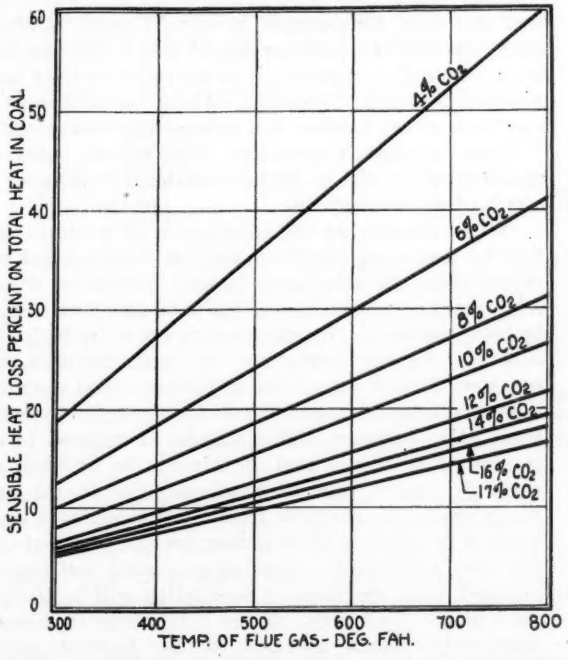


FIG. 5. PERCENTAGE OF HEAT LOSS IN FLUE GASES BASED ON TOTAL HEAT VALUE OF AVERAGE COAL WITH DIFFERENT PERCENTAGES OF CO_2 IN GASES

then the coal is sufficiently fine. With regard to actual screen-tests, the best figures for these, from a practical point of view, will vary with different fuels; anthracite should be powdered more finely than a bituminous coal, while the length which the flame has to travel will also affect this question. The average powers for a turbo-pulverizer are best expressed as a percentage of the power developed by an efficient boiler plant, and with coals of various calorific value. Figure 1 shows these percentages, and it will be seen that 2 per cent is a very fair figure to take.

Magnetic separators have been referred to as an essential part of a powdered-fuel plant. There is no doubt that a magnetic separator, when installed, would somewhat reduce the maintenance charges, while the unlikely occurrence, with a properly designed plant, of a breakdown through large quantities of "tramp iron" may be avoided. A good rule to follow is to make the plant capable of passing "tramp iron" to an extent which is met with in the average coals. But if the plant is large and the pulverizer or pulverizers are fed by means of a coal-handling plant, it is advisable to install a separator in or over one of the conveyors. If, however, only one unit is installed, it is doubtful, if the first cost of a magnetic separator warrants its installation.

Combustion of powdered fuel has received perhaps less attention than the two foregoing operations, and

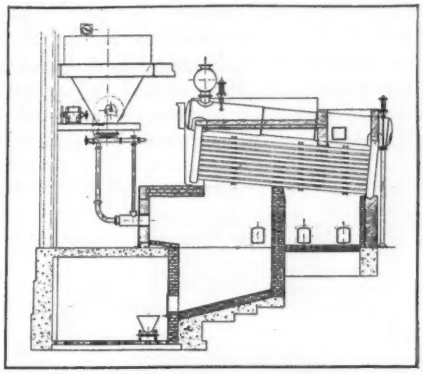


FIG. 6. TYPICAL ARRANGEMENT OF POWDERED COAL STORAGE

yet there is more to be learned in this connection and many more pitfalls than in the design of a satisfactory drier, a grinder, or a pulverizing mill. It is not enough to lead powdered fuel, of the right degree of fineness, thoroughly mixed with the correct amount of air for its combustion, into a large refractory-lined chamber. The shape, the volume of the combustion chamber, the position of the ash pockets, direction of the flame and velocities must be all carefully considered from a practical and technical point of view. A large combustion space is necessary, but, to reduce radiation losses, this space should be so arranged that the bulk of the heat is near to, or on, its work. Figure 2 shows the arrangement of a turbo-pulverizer firing a "Woodeson" boiler. A large combustion chamber is shown, but it is so arranged that the flame is parallel to, near to, or underneath, the boiler tubes. If the same space was made use of as diagrammatically shown in Fig. 3, it is obvious how much more heat would be lost by radiation and how much would be lost owing to the fact that the most luminous flame is not adjacent to the water tubes. The velocity also is of first importance, and most of the earlier failures in powdered-coal firing could be traced to too high velocities.

Furnace pressure in a powdered-fuel-fired boiler furnace should be so near to what may be called a balanced draft that there should be a slight vacuum at the base, a neutral pressure in the middle zone, and a slight pressure at the first pass. The powdered coal and air at the burner should be of sufficient pressure to allow the flame to wander in and to avoid anything in the nature of a blow-pipe action, causing scouring and numerous other troubles. It is found that, owing to the rapid combustion, the gases leaving a boiler fired with powdered coal are usually lower in temperature than the gases from a boiler working at the same rating and fired either

by means of a mechanical stoker or by hand. It is quite possible to maintain the CO_2 readings of 16 per cent and over.

There is another great saving to be obtained with powdered coal firing, and this refers more particularly to the ash. It is often found that from 12 to 14 per cent and in some cases—which are by no means so rare as one would think—up to 40 per cent of unconsumed carbon is taken away with the ashes from below a hand-fired or mechanically-fired boiler grate. Figure 4 shows the loss in the heating value of the coal, with different true ash percentages of unconsumed carbon in the ash taken away from the ashpit.

With regard to flexibility, the taking of peak loads and the elimination of banking and damping, a powdered-fuel plant, suitably designed, is just as convenient as gas or oil. Starting up after a week-end or a night stoppage, either in connection with a boiler or a metal-

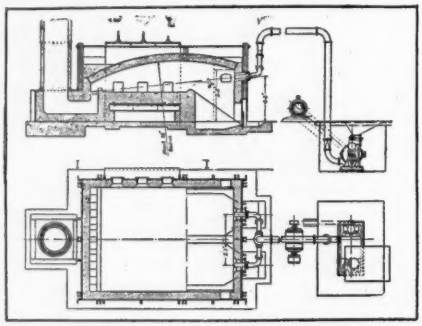


FIG. 7. ARRANGEMENT OF UNIT SYSTEM OF DELIVERING POWDERED COAL TO A FURNACE

lurgical furnace, can be carried out much more quickly. In practice, this of course means a material saving in coal burned over a lengthy period. With a suitably-designed powdered-coal-fired boiler, together with superheater and economizer, there appears no reason why an overall efficiency of 86 per cent should not be maintained over a lengthy period and not just during an acceptance test.

Considerable attention has been paid to combustion chamber linings, and it is evident that this question has caused a lot of trouble. Probably this trouble is caused by the incorrect design of the combustion chamber, too high velocity, and the choice of the wrong refractories. To withstand the undoubtedly high temperatures, a theoretically correct design is necessary. The velocity of the gases must not be so high as to cause any scouring, or severe impinging, while if the ash of the coal being used is melted and contains a high percentage of ferric oxide, a high silicious brick should not be used.

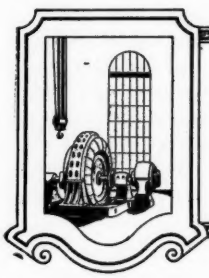
Regarding bird-nesting on the tubes of water-tube boilers, here again there has been much discussion with regard to the necessity of steam blowers or other devices for removing the deposit from the tubes. There is no more necessity to install these devices in connection with a powdered-coal-fired boiler than there is with a boiler fired by means of a grate. If ash does adhere to the first row of tubes at any time, this can be easily removed by slight regulation of the flame. If the combustion chamber is incorrectly designed or the velocity of the flame is too high, it is quite possible to get a sticky deposit of partly-consumed carbon upon the water tube, which no steam blower will affect, let alone remove; but, with installations Mr. Atkinson has watched, any trouble of this nature has in the earlier cases been overcome, and latterly has been non-existing. A very similar point arises when considering certain metallurgical processes. In this case, the combustion chamber should be so designed that the changes of direction of the flame deposit the ashes in the combustion chamber and not beyond the bridge.

At one time it seemed that, with boiler propositions at any rate, and when using certain coals, the difficulties arising in connection with ash-handling would hinder progress. It has now been found, however, that ash can be taken away from a boiler or furnace combustion chamber in two distinct forms: (1) Liquid slag, which solidifies when exposed to the atmosphere; (2) dust, or slightly nodulized dry ash. With regard to the liquid slag, this is about the easiest form of ash to obtain with all coals, with perhaps the exception of a fuel the ash of which has a very high fusion point and which has been met with, for example, at certain South Staffordshire collieries. If, however, liquid slag is forming in a large combustion chamber, it is advisable to have some mechanical means of removal. About the most convenient form of ash-handler is a water-cooled conveyor.

Dust, or slightly nodulized dust, can be easily removed from a boiler or furnace combustion chamber by means of an ordinary rake.

When considering the installation of a central station for preparing powdered coal, all elevators and conveyors after the drier must be of a dust-proof nature. After storage, powdered coal has to be distributed either by low-pressure air, by screw conveyors or by high-pressure air. In the case of the two latter methods, it is necessary to have some form of powdered-coal storage at the units being fired, and Fig. 6 shows a typical arrangement. Mr. Atkinson stated that he is opposed to any storage of powdered coal, if this can be avoided, and certainly any storage of powdered coal at the units being fired. An overflow from these bins might occur, while if the plant is left standing for any length of time, say over a week-end, unless all powdered coal bins are emptied, slow spontaneous combustion will be likely to take place. The plant at the Hammersmith Borough Electricity Works operates on the Holbeck system. Only one storage of powdered coal is made use of, and not at the units being fired. With the unit system, after the coal has been pulverized in the machine it is delivered directly with the air for its combustion to the burner or burners, as indicated in Fig. 7, and therefore at any given moment only a very small amount of powdered fuel is in being.

ACCORDING TO REPORTS, the Bureau of Mines is undertaking the investigation of combustible peat deposits in the United States, by direction of Secretary Work of the Interior Department. About $50,000 remains unexpended from appropriations and is available for this investigation. In previous searching inspections, the Dakota lands have been given considerable attention in quest for lignite. The work now will be devoted mainly to peat and it is understood that Senator Fletcher is requesting that Florida be included in the fields to be investigated, for the purpose of definitely determining to what extent, if at all, peat deposits are available in Florida.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Inductive Alternating-Current Circuits---I

General Nature of Inductance and Reactance Considerations Leading to the Idea of Power Factor. By E. K. McDowell*

AS STATED in the article, Non-Inductive Alternating Current Circuits, which appeared on page 633 of the June 15, 1923, issue, alternating current transmission lines may be classified broadly into two types, those in which the capacitive and inductive effects are of importance and those in which the effects of these properties may be neglected. Non-inductive circuits having been treated in that article, we will now take up the discussion of circuits in which the inductive effects are of importance, but in which the capacity effects are not considered.

Before taking up the discussion of inductive circuits in detail it will be advisable to explain the general nature of inductance. In elementary electrical theory the familiar principles are developed that (1) if a current flows in a straight wire there will be electromagnetic stresses set up "in circles" about the wire; and if the wire be formed into helical coil of a number of turns, these stresses (or the magnetic field) are greatly increased. Also (2) if a loop of wire is caused to move through such a magnetic field there will be an e.m.f. set up in the loop, and a current will be caused to flow therein. This is provided that the loop be moved in such a manner that it "cuts lines of force"; i.e., so that the strength of the magnetic field about the loop is continually varying.

Obviously the same effect would take place if the loop were stationary, and the magnetic field surrounding it were caused continually to "grow" or spread, and then diminish: such as would be the case, say, if the current in the primary wire were continually to reverse in direction at regular intervals, with a steady increase from zero to a maximum at each reversal.

The conditions just outlined represent fairly well what takes place in an inductive a.c. circuit. The main current is continually varying, and periodically reverses

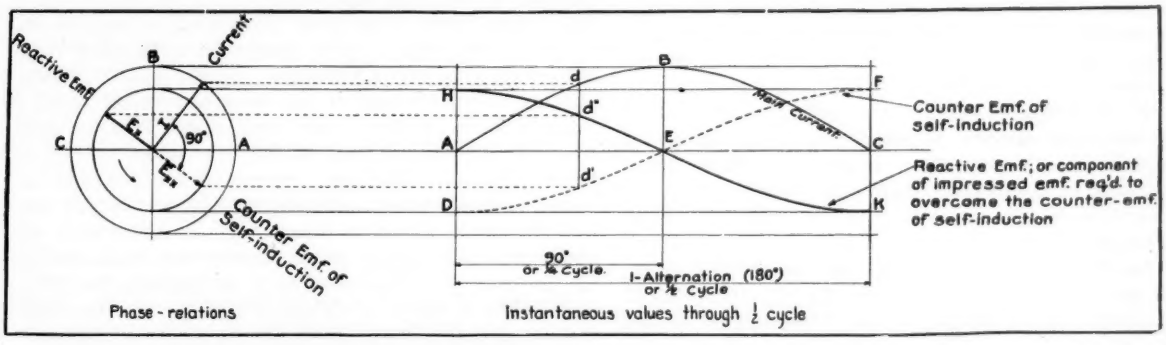


FIG. 1. RELATIONS OF CURRENT, SELF INDUCTANCE COUNTER-E.M.F., AND REACTIVE E.M.F.

Before taking up the discussion of inductive circuits in detail it will be advisable to explain the general nature of inductance. In elementary electrical theory the familiar principles are developed that (1) if a current flows in a straight wire there will be electromagnetic stresses set up "in circles" about the wire; and if the wire be formed into helical coil of a number of turns, these stresses (or the magnetic field) are greatly increased. Also (2) if a loop of wire is caused to move through such a magnetic field there will be an e.m.f. set up in the loop, and a current will be caused to flow therein. This is provided that the loop be moved in such a manner that it "cuts lines of force"; i.e., so that the strength of the magnetic field about the loop is continually varying.

Obviously the same effect would take place if the loop were stationary, and the magnetic field surrounding it were caused continually to "grow" or spread, and then diminish: such as would be the case, say, if the current in the primary wire were continually to reverse in the direction of flow. This sets up a continually-varying magnetic field about the line conductor; or in the coils of any electrical apparatus that may be connected in the circuit. This varying magnetic field, in turn, sets up, or induces, a counter-e.m.f. both in the conductor itself and in any adjacent parallel conductor belonging to the circuit; or (in case of electrical apparatus) in adjacent coils of the conductor itself.

Since alternating-currents are continually varying this counter-e.m.f. is generated, and is present in the circuit, whenever current is flowing therein; and is referred to generally as the counter e.m.f. of self-induction.

This counter-e.m.f. is always set up in such direction as to oppose the flow of the main current; because if the reverse were true the current-flow would be increased indefinitely without added expenditure of energy, which is of course impossible. The inductive e.m.f. varies and reverses periodically similarly to the alternating current producing it; but is not in phase with that current, nor is it in phase with the voltage impressed on the circuit. It will, however, vary in a sine-wave form if (and as) the current producing it varies in sine-wave form; as is commonly assumed for alternating current. The magnitude of such e.m.f., induced in a conductor, varies as a direct function of the rate at which said conductor is cut by magnetic flux but these lines of force, as al-

*Chief engineer, Donora Steel Works, American Steel and Wire Co.

ready explained, emanate outward from the center of the conductor in concentric form; expanding outward as the current increases, and contracting as it diminishes. Also the rate by which the conductor is cut by these lines of force is proportionate to the rate of change of the main current. But this rate of change must be greatest when the current is passing through its zero value, as at points A and C in Fig. 1, therefore the induced counter e.m.f. will be a maximum at these instants (as at D and F, Fig. 1). Furthermore the rate of change of the main current is zero when it is at its maximum value (B) during each alternation, or half-cycle; and the induced counter-e.m.f. will accordingly be zero at that instant; as in E in Fig. 1.

Since any induced e.m.f. must be in such direction as to oppose the current producing it, it follows from the above that the curve of variation of the counter-e.m.f. of self-induction must be in such relation to the main current-curve as is shown in Fig. 1 by the dotted curve DEF.

It follows therefore that the counter-e.m.f. of self-induction always lags 90 deg. behind the current in phase. The main, or impressed, e.m.f. will thus be opposed in all its changes by this counter-e.m.f.; or, similarly, changes in the current are opposed at all points in the cycle by this counter-e.m.f. of self-induction. When the current (or the main e.m.f.) is positive and decreasing the counter-e.m.f. is positive and increasing: similarly when the current is positive and increasing the counter-e.m.f. is negative and decreasing. The induced e.m.f. therefore tends to retard the "building-up" of the current, which occurs during the first half of an alternation (as between points A and B in Fig. 1); and also tends to prevent the decrease in current-flow—from max. to zero, that occurs during the other half of each alternation or half-cycle, as from B to C on the figure referred to.

The general result of these conditions is that the current, which in a non-inductive circuit would be in phase with the impressed e.m.f., is "impeded" (as just described) by the counter-e.m.f. of self-induction and is caused to lag behind the impressed e.m.f. by some phase-angle; which is proportionate to the self-induction-counter-e.m.f; and thus is proportionate to the amount of inductance in the circuit.

Reactive E.M.F. and Energy E.M.F.

For convenience in calculating the performance of inductive circuit, as well as to render these inductive effects more easily understood, it is customary to consider the impressed e.m.f. as resolved into two components; one of which is, in amount, just sufficient to overcome or neutralize the counter-e.m.f. of self-induction, and will be referred to hereinafter as the Reactive E.m.f. The other one of the two components will be, in amount, sufficient to be effective against the true resistance of the circuit; and will be referred to as the Energy E.m.f. It will be the e.m.f. that impels the current, and will be in phase with the current; and may be thought of here, provisionally, as the e.m.f. necessary to overcome the resistance of the circuit.

Reactive e.m.f., being of such amount and in such phase relation as just to neutralize the counter-e.m.f. of self-induction, will be equal to that counter-e.m.f. in amount but will differ therefrom by 180 deg. in phase. Therefore the curve of variation of the reactive e.m.f. through an alternation must be in such relation to the main current curve as represented by the curve HEK in Fig. 1. At any given instant, as at d on the current-curve ABC, the reactive e.m.f. E_x, the current I, and the counter-e.m.f. of self induction E_{xx}, are in the respective phase relations shown by the vectors at the left of Fig. 1. It is evident that the reactive e.m.f. must lead the current by 90 deg. in phase in order to oppose and to overcome the counter-e.m.f. of self-induction, E_{xx}, which lags behind the current by 90 deg. in phase. Putting it in another way it can be said, then, that the current lags behind the reactive e.m.f. by 90 deg. in phase.

Relations of Impressed E.M.F., Energy E.M.F. and Reactive E.M.F.

It follows that, in any inductive a.c. circuit (without capacitance), there are three e.m.f.'s to be considered:

(1) The impressed e.m.f.

(2) The reactive e.m.f. (equal in amount to the counter-e.m.f. of self-induction, but opposite thereto in phase)

(3) The energy-e.m.f. (or e.m.f. that impels the current against the line resistance)

and it also follows that these three e.m.f.'s must be in the phase and quantitative relations to each other that are indicated in Fig. 2 following. These relations, which are generally expressed in the more convenient vector-diagram form of Fig. 3, are represented here as they would be in a circuit such as that illustrated in Fig. 4 below. In this "imaginary" circuit all the power is assumed to be expended in driving the current through the line resistance R and in overcoming the inductance of the circuit; the latter being represented symbolically by the coils X. This imaginary, or hypothetical, circuit of Fig. 4, which is without any motor or other load connected thereto, is assumed here in order to illustrate certain relations that can be more conveniently explained apart from the influence of any connected load. Relations in circuits having load connected thereto, which is the usual actual condition, will be considered later.

Relations of E.M.F. Components and Current in "Load-Less" Circuits

Some further explanation is necessary at this point in order to show just how the vector relations of Figs. 2 and 3 apply to this imaginary "loadless" circuit of Fig. 4. The energy-e.m.f. E_1 is the e.m.f.-component that impels the current against the line-resistance; it is therefore in phase with the current. The reactive e.m.f., E_x, being the e.m.f.-component required to overcome the counter-e.m.f. of self-induction, will lead the current by 90 deg. in phase. Therefore E_x will lead E_1 by 90 deg. of phase-angle; which establishes the phase-relations of these two components, as shown in Fig. 2.

In the assumed circuit Fig. 4, however, all of the impressed e.m.f. E is expended in impelling the current against line resistance and in overcoming (or neutralizing) the counter-e.m.f. of self-induction. Therefore it follows that E_1 and E_x are components of E, the impressed e.m.f. In other words E, E_1, and E_x must be, vectorially, in the relation shown in Figs. 2 and 3; the impressed e.m.f., E being of such value and at such phase-angle that it is the resultant, or vector-sum, of E_1 (the energy-e.m.f.) and E_x (the reactive e.m.f.).

It is thus shown that Figs. 2 and 3 correctly represent the relations of impressed e.m.f., reactive e.m.f., and energy-e.m.f., in such a circuit as shown in Fig. 4. It is seen that the e.m.f. E is the resultant of the energy-e.m.f. and the reactive e.m.f.; and is thus the e.m.f. required both to impel the current against the resistance R, and to overcome the inductance X, of the circuit; therefore E is the impressed e.m.f., or the sending-end e.m.f. As further ascertained from Figs. 2 and 3 the energy-e.m.f. E_1 (together with the current) lags behind the sending-end e.m.f. by the angle P (degrees) in phase.

Reactance

Thus far the circuit conditions described have been such as would obtain in a circuit like that shown by Fig. 4; without connected load, and consisting only of line resistance R and an inductance, designated by the coils X but not yet definitely localized. Assume now,

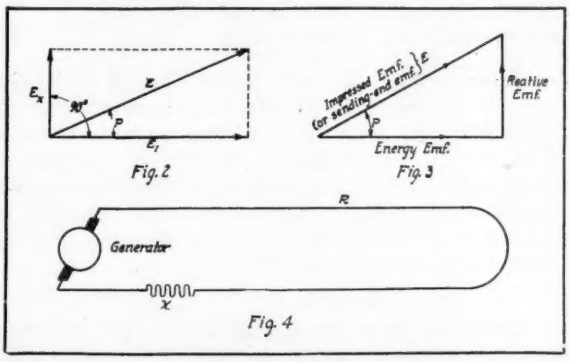


FIG. 2. PHASE AND QUANTITATIVE RELATIONS OF THREE E.M.F.'S IN INDUCTIVE CIRCUITS

FIG. 3. VECTOR DIAGRAM OF E.M.F. RELATIONS

FIG. 4. SIMPLE CIRCUIT TENDING TO PRODUCE E.M.F. RELATIONS SHOWN IN FIGS. 2 AND 3

still using this "loadless" circuit of Fig. 4, that the inductance X represents the inductive effect set up in one wire by reason of the magnetic lines of force, cutting said wire, which emanate both from that conductor itself and from the other (parallel) conductor of the circuit, as previously explained.

It has already been stated that the magnitude of these line inductive effects depends upon the frequency (cycles per second), the size of the conductors, and the spacing between them. This line inductance constitutes a definite opposition to current-flow in the circuit-conductors; and causes an additional drop in voltage in the circuit over and above the voltage-drop caused by line-resistance. However (1) the inductance of this "loadless" circuit is all to "line" inductance; also (2) by reason of this line inductance, a counter-e.m.f. is set up in the circuit, which is opposed and neutralized, we have seen, by the reactive e.m.f. This means that, in a circuit like Fig. 4, without connected load, the voltage-drop due to line inductance will be identical with the reactive e.m.f. E_x of Figs. 2 and 3.

Since line inductance causes a voltage-drop somewhat as does line resistance the opposition to current-flow caused by these line inductive effects can be expressed, like resistance, in ohms. When so expressed the opposition to current-flow due to line inductance is referred to either as Inductive reactance or simply as Reactance; and is quantitatively expressed as ohms per unit length (usually per mile or per 1000 ft.) of one conductor.

Reactance Tables

As a matter of practical calculation procedure, the inductive reactance of a given circuit, of known current-frequency and known size and spacing of conductors, is readily determined from tables which give this reactance in ohms per 1000 ft. or per mile of single conductor for the usual range of sizes and spacings of conductors, and for the two usual frequencies of 25 and 60 cycles per sec. Tables of this character will be presented in a later article; and such tables can be found in most hand-books and reference-works on electrical engineering.

Finally, the total reactance of the circuit, X (in ohms), is obtained by multiplying the unit-reactance per mile (or per 1000 ft.) by the total length of conductor in the circuit—expressed in the same units of length.

Relations of Reactance and Reactive E.M.F.

As previously stated the unit reactance values in the tables are given in ohms; in other words the unit values are so calculated that, if the reactance of the circuit, X (ohms), be multiplied by the current I (amps) flowing therein, the product will be E_x, the reactive e.m.f., or voltage drop caused by forcing the current against the inductive reactance of the circuit. Or, as expressed in equation form

$$E_x = I\ X \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

where E_x is the reactive e.m.f. (or voltage drop due to overcoming line reactance), I is the current (amps) flowing in the circuit; and X is the total inductive reactance of the circuit-conductors, in ohms.

The similarity in form of equation (15) to the equation for line-resistance-drop ($E_1 = IR$) should be noted. In this connection note, also, that the total line-resistance R of a circuit can be said to represent the voltage-drop due to a current of 1 amp. flowing through the resistance of the circuit.

Similarly, the total line reactance X of a circuit can be regarded as expressing the reactive e.m.f. in volts, or the reactance-volts drop, due to a current of 1 amp. flowing through the inductive reactance of the circuit. These statements, regarding total line resistance and line reactance, become at once apparent by substituting $I = 1$ amp. in the two equations (for E_1 and E_x respectively) just referred to.

Relations of reactive e.m.f., energy-e.m.f. and sending-end e.m.f. can now be more specifically defined; as applying to a "loadless" circuit, like Fig. 4. Referring to Fig. 3 on the same page, it is seen that the reactive e.m.f. E_x of the (Fig. 4) circuit can be calculated from the current I and the total line reactance X. Also, for the kind of circuit being considered, the energy-e.m.f. E_1 is the resistance-drop, and can be figured by, say, equation II (page 635, June 15, 1923, issue). These e.m.f.'s, E_1 and E_x, are in quadrature, therefore they cannot be added arithmetically; but their combined effect is their vector resultant, E, as indicated on Fig. 3.

It should now be evident that E, as thus determined, represents the sending-end e.m.f. for a circuit like Fig. 4, where all the energy is expended in overcoming

line resistance and line reactance. E also represents, for such conditions, the resultant voltage-drop due to the combined effects of line resistance and line reactance; and, in this connection, is sometimes referred to as the impedance e.m.f.

General Aspects; Circuits with Conn. Load

The preceding matter has outlined the relations of reactive and energy-e.m.f. components and current as for an imaginary circuit without load. Methods of calculating the properties of such a circuit have been referred to in a general way and for illustrative purposes only; with the idea that the principles outlined could be more easily understood from the general standpoint of practical calculations.

These characteristics, and the methods referred to for calculating them, also apply in a similar manner to circuits having load connected thereto, to the extent of determining the line impedance-e.m.f., i.e., the voltage-drop due to the combined effects of line resistance and line reactance. The application of these principles to such circuits is, however, modified in certain particulars in order to include the effects of load power-factor. The properties of this more usual class of circuits will be developed in a subsequent article, but before proceeding to this it is convenient at this point to outline, in some detail, the general nature of power-factor. This will be done, mainly with reference to the "load-less" circuit previously discussed, in the next article of this series.

Electric Motor Drive in the Textile Industry

Selection of Motors for Use in Textile Mills Requires a Close Knowledge of Machinery Characteristics. By Gordon Fox

WITH RESPECT to the horsepower of electric motors installed, the textile industry ranks second, only the steel industry exceeding it in this respect. The machinery of this industry has become fairly well standardized, due to its long use and development. A multiplicity of machines are used in the fabrication of cotton, wool, linen and silk. As many of the machines are similar and as the cotton mills predominate, we will consider primarily the cotton preparation, spinning, weaving and finishing processes, covering the principal machines used and those involving special points of interest. First let us consider briefly the nature of these processes.

Picking

Cotton is received at the mill compressed in bales, in a matted condition and mixed with impurities. The bales are broken and the cotton opened into a loose, fleecy state, by passing between pairs of coarsely toothed rollers, each pair traveling successively faster. The cotton is then put through pickers whose function it is to loosen the matted condition and to straighten the fibres and produce some uniformity.

Carding

For this process, the machine principally used is the revolving flat card. This machine consists essentially of a large cylinder, about 40 in. diameter and 40 in. wide, the surface of which is covered with myriads of fine wire teeth set in a cloth foundation. Surrounding the upper portion of this cylinder and separately supported is an endless belt of "flats" also covered with teeth. This machine removes the short fibers and small impurities and arranges the fibers in approximate parallel order.

Material intended for fine yarn or coarse yarn of high quality is combed after carding to remove short fibers and improve the alinement. The sliver goes through a lap machine, reducing the sliver to lap about 1 ft. wide. This lap then enters the combers equipped with cylinders partially covered with rows of needle combs. Six or more laps going through the machine simultaneously are combined, condensed and formed into a continuous sliver.

After carding, the cotton goes through a drawing process, the functions of which are: to improve the uniformity by "doubling" or superimposing layers to diversify the inequalities; to improve the parallel arrangement by drawing or pulling the fibers into line and to attenuate the sliver and reduce it from about ¾ in. diameter to about 1/16 or 1/32 in. diameter, in which form it is known as "roving."

Spinning and Twisting

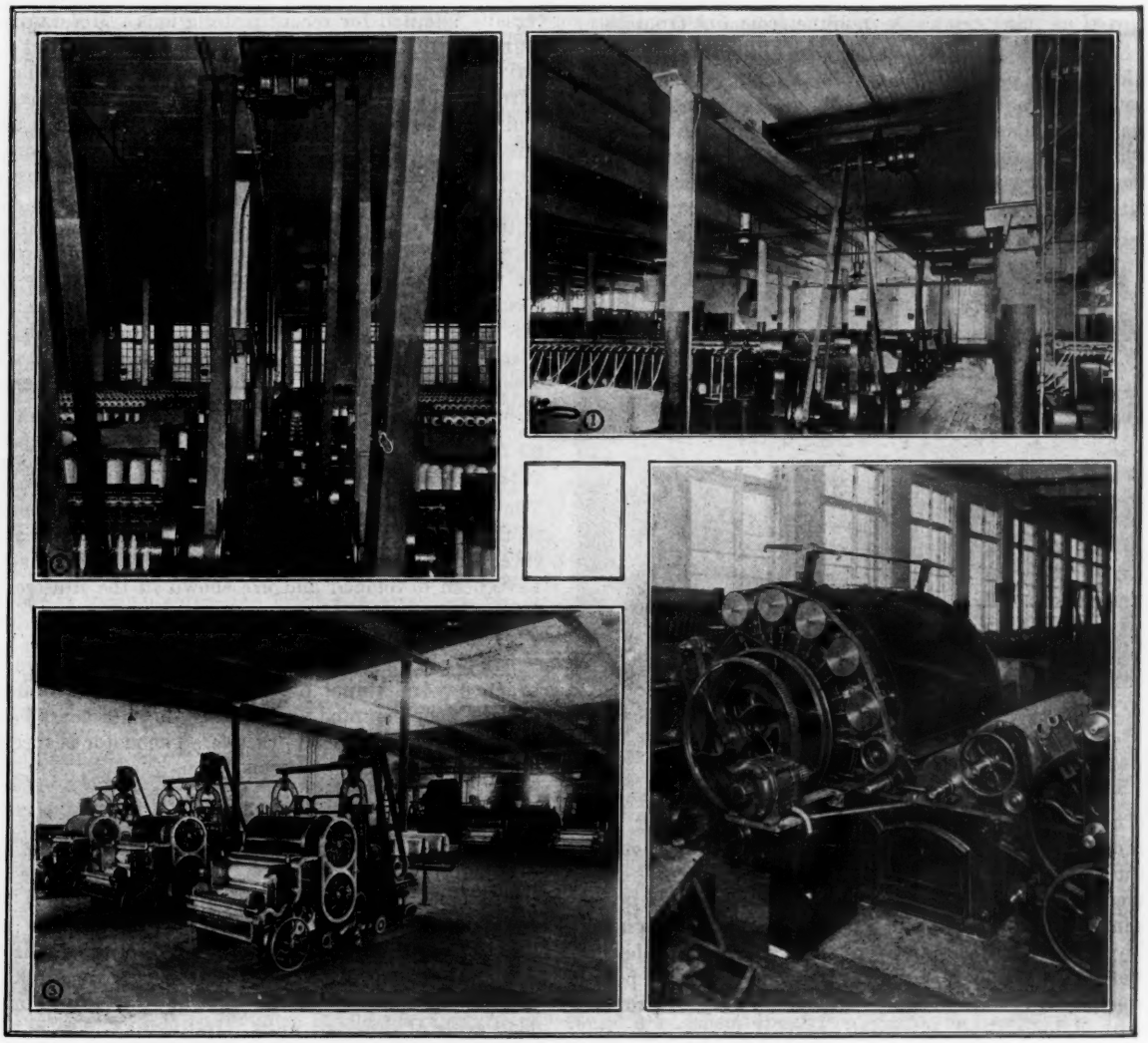
In the spinning process the loose roving is twisted into yarn or thread sufficiently firm and strong for weaving. Two entirely different machines are used for this purpose, the "mule" and the "ring spinning frame"; the latter is more common. The mule is a rather complex machine acting on the principle of first winding the yarn upon a spindle and then drawing it off from the end, giving a twist for every turn on the spindle. The ring spinning process is continuous. Bobbins of roving are placed in creels at the top of the ring spinning frame. From each bobbin the roving passes through feed rolls, then through a guide ring and downward above the end of a winding spindle and bobbin to a "traveler" which clips loosely a steel ring or track fixed on a movable plate called the ring plate. Each time the ring encircles the bobbin it causes one twist in the yarn. The ring plate is caused to move up and down to distribute the winding on the bobbin.

Weaving

Weaving consists in interlacing the warp and the weft on a loom to form cloth. The threads or yarn running lengthwise of the piece is the warp, the crosswise yarn is the weft. A loom has five principal motions, viz., shedding, picking, wefting, setting up and letting off. The shedding motion divides the warp yarns into two lines or sections by elevating some and depressing others. The picking motion impels the shuttle through the opening or shed between the elevated and depressed lines of warp. The wefting motion then beats the weft yarn into close contact with the "fell" of the cloth. The setting up motion takes up on the cloth and the letting up motion unwinds by small increments, the yarn from the beam. For weaving different colors, two or more shuttles are used.

Textile machines in general, require relatively small amounts of power so that with the extensive use of individual drive, the average motor size is now about 3 hp. Most textile machinery involves high rotative speeds and continuous running at constant speed. Not only is constant speed desired, but it is important that the speed be uniform in order to minimize breakage of the delicate yarn or thread and also to improve the uniform quality of the product. It is desirable that speeds be maintained at the maximum permissible values, as and woolen mills is highly inflammable. Sixty cycles is the common frequency, being well suited for the high-speed motors required. It may be noted that the extensive use of high-speed motors results in good efficiency and power factor. Most textile mills use 550 v., three-phase power.

Standard induction motors will not withstand satisfactorily the operating conditions in the textile mill. The ever present lint from the cotton or wool is drawn into the motors, obstructing the ventilating ducts and



FIGS. 1-4. VARIOUS APPLICATIONS OF ELECTRIC MOTOR DRIVES IN TEXTILE MILLS

Fig 1. Two-frame drive of slubbers. Fig. 2. Four-frame drive of ring-spinning machines. Fig. 3. Individual drive of single picker. Fig. 4. This woolen card machine has an individual geared drive.

production is directly affected by any decrease in driving rate. The great advantage afforded by individual drive lies in the elimination of speed losses and fluctuations due to belt slippage.

Except in the finishing departments the alternating current induction motor is used almost exclusively in textile mills. The characteristics of the induction motor are well suited and the absence of fire risk is an important consideration, as the lint which is present in cotton causing overheating. This is not so serious in the case of large, group drive motors but merely requires liberal rating and frequent cleaning. With the smaller motors, it tends to be more serious due to the smaller clearances and air passages. Trouble from this source is reduced in some motors of moderate size by eliminating air ducts and making the interior of the motor accessible for cleaning. The smallest motors are usually totally enclosed. This is most effective and, in the case of ex-

tremely small motors, does not materially increase the size and cost. It is a common practice to semi-enclose the motors with screening, perforated sheet metal having been found effective and most readily cleaned and maintained. The presence of lint leads to bearing troubles also. Lint enters ring oiling bearings, clogs the oil grooves and drain and prevents the rings from turning. It also collects and draws oil from the bearings by capillary attraction. Dripping oil is particularly objectionable around textiles. Where oil ring bearings are necessary, they must be dust proof by sealing the joints with gaskets. Waste packed bearings are extensively employed as being relatively immune from lint troubles.

It is necessary to maintain high humidity in a textile mill for proper working of the material. This does not cause trouble when the motors are running but does lead to condensation and penetration of the windings when the motors are shut down. It is necessary to treat the windings specially to withstand this moisture condition.

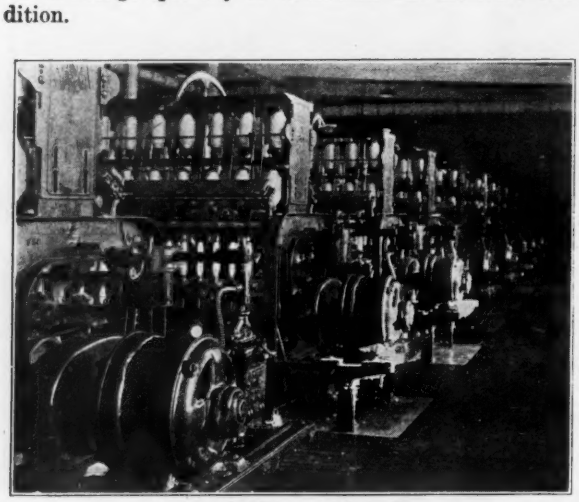


FIG. 5. INDIVIDUAL MOTOR CHAIN DRIVE OF RING SPINNING FRAMES

As an outgrowth of group drive, there has developed a method of driving two to four drawing, roving, spinning or twisting frames from one motor without an intermediate countershaft. In the "four-frame" drive, a ceiling mounted motor may be equipped with a double shaft extension, each end carrying a double crown pulley from which belts drive to tight and loose pulleys on the frames below. If the aisle spacing does not permit this arrangement, one end of the motor may be provided with a long shaft extension, carried in part by self-alining outboard bearings. The drive pulleys may all be placed on this extension or a short extension on the other end of the motor may also be used, depending largely on space consideration. "Two-frame" drives are similar to "four-frame" drives except that smaller motors are required and but two frames driven from one motor. Figures 1 and 2 show some two and four-frame drives.

Motors used for four-frame drives are about 15 to 30-hp. capacity. As no adjustment is possible, heavy belt tension is the rule and liberal shafts and bearings are required. Oil ring bearings are employed because of the high speed and heavy belt tension. The inside motor bearing should be split when a long extension is provided with outboard bearings. It is best not to exceed a motor speed of 1200 r.p.m. in order to prevent the use of too small pulleys, excessive belt tension, vibration and bearing troubles. Motors of the open, accessible type are commonly supplied. As the motor starts without load, low slip rotors may be used, resulting in good speed regulation at the motor but more or less belt slip is inevitable.

Pickers

For pickers, the advantages of individual drive are generally recognized and this method is almost universally adopted for recent installations. Motors direct connected to the beater shaft have been used, but belt drive to the beater shaft from a motor mounted on an A frame above the machine now prevails. A screened, squirrel cage motor with waste packed bearings is used, this motor having a moderately high starting torque. Motor sizes of 5 to 10 hp. are most common. There are two methods of driving double beater pickers. Two motor drive is preferred, the motors being mounted, one on each side of the machine on the A frame and driving the respective beater shafts. With single motor drive, a special double extended shaft is necessary. The long extension reaches across the machine through an outboard bearing beyond which one pulley is located. The other pulley is mounted on the other short shaft extension of the motor.

Cards

Group drive is still used most extensively for cards. The principal requirements is a high starting torque due to the weight of the cylinder, this torque being about three times running value. Suitable individual motors have been developed and are shown in the illustration.

Drawing Frames

Two or four-frame group drive is the prevailing practice. Individual drive by squirrel cage induction motors, floor mounted and driving through gears is said to be common European practice. The motor is specially adapted to give smooth acceleration.

Spinning Mule

The load of a mule is cyclic in character and of a decidedly fluctuating nature. These machines are commonly belt driven, either singly or in small groups, from induction motors provided with high resistance rotor and operated in connection with flywheel to equalize the demand. Group drive may lead to speed variations owing to superposition of the high and low points of the load cycle of different units. Individual drive is therefore preferred by some as giving more uniform speed and increased production.

About 50 per cent of the total power in a mill is used in the spinning process and, as ring spinning frames prevail, much attention has been given to the drive of this type of machine. Four-frame drive has been often adopted in the past, but is objectionable, primarily because the belt slip leads to loss of production. It is also difficult to start by belt shifting smoothly enough to prevent thread breakage. The spinning frame is a constant running machine for which well maintained speed is particularly important. A rather heavy starting torque is demanded and the rate of acceleration must be just right. Too low a torque will not insure starting and

too high a torque will cause too quick a start, breaking the yarn. Moreover, it is necessary to run the frame at different speeds for different weights of yarn. The load of the machine is largely friction and thus has approximately a constant torque characteristic, but heavier yarns slightly increase the load.

Squirrel cage induction motors with properly suited torque characteristics are most commonly employed for this application. These motors may drive through gears, a change in ratio being employed to obtain a change in machine speed. Fiber, rawhide or cloth gears may be used but, vibration, noise and wear are troublesome. Silent chain drive has been found well suited to this service. This drive is positive, it permits speed change by changing sprockets, it introduces desirable flexibility and eliminates the noise and vibration incident to gear drive. With either gear or chain drive, 1800-r.p.m. motors may be used, affording advantages in first cost, efficiency and power factor.

Motors running at 1200 r.p.m. are sometimes direct connected to the cylinder shaft. If a squirrel cage motor is so applied, it does not permit of speed adjustment for spinning different yarns. Wound rotor motors with secondary resistance control have been successfully employed. The speed controlling resistance is finely graded.

Most spinning frame motors are 5 or 7.5 hp. The size used depends upon the size of frame and number of spindles, the size of yarn spun and the speed. The cotton bands which drive the spindles are subject to shrink and stretch with varying humidity, affecting the power requirement considerably. Single speed also affects the power, higher speeds increasing the load. Twister frame motors range from 5 to 20 hp. depending upon size and material handled. Spinning frame motors are thrown across the line whereas compensators are required for the larger twister frames to prevent too sudden starting. These motors are of the screened type with waste packed bearings.

Looms

Individual motor drive is particularly beneficial as applied to looms. The rotative speed is low, the parts reciprocating and the load has cyclic fluctuations. With belt drive the speed varies through the cycle so the average speed is materially less than the maximum. This speed variation reduces the output and produces poorer quality cloth, particularly on loosely woven fabrics. It also leads to more thread breakage and loom fixing. Individual motor drive affords a relatively closely maintained speed and thus largely overcomes the above difficulties. A motor of 1200 or 1800 r.p.m. is used, usually geared to the loom. There is more or less vibration to the machine due to its reciprocating parts so that a fairly rugged motor is desirable. These motors are small in size, the smallest cotton looms requiring ⅓ hp. and the large carpet looms about 3 hp. Motors may well be totally enclosed and equipped with waste packed bearings.

Because of bearing friction and inertia of the reciprocating parts, a rather high torque is required to start a loom. It is necessary in many cases to stop the loom at frequent intervals to replenish the shuttle, also to repair threads or make adjustments. Automatic devices are now installed on some looms for changing shuttles, minimizing the number of stops. It is desirable to accelerate quickly in order to minimize delay. In some cases a cage motor with high torque characteristic is used, driving positively to the loom. In other cases a low torque motor is run continuously and the loom is started and stopped by a clutch. The first arrangement is mechanically simpler but sacrifices speed regulation and efficiency to a small extent.

Finishing

Finishing is a distinct branch of the textile industry, this work often being done in a separate plant. The principal processes are bleaching, dyeing, mercerizing, printing and finishing. Methods vary widely according to the kind of cloth and the finish desired.

About half of the machines in the finishing plant require speed changes. The requirement for adjustable speed has been met primarily by the use of adjustable speed direct current motors. Wound rotor induction motors and brush shifting a.c. motors are also used. The approximate constant torque characteristic of most finishing machine loads is favorable. The principal advantage of the a.c. motor is the avoidance of a direct current supply. These motors do not equal the direct current motor in characteristics, however. A lesser speed range is afforded, speed adjustment and regulation are less accurate and control less convenient. This method may be satisfactory for some singeing machines, calenders, mangles and tentering machines where a wide speed range may not be necessary. For printing machines particularly, the direct current motor is superior. Alternating current drives are more feasible where cheaper grades of cloth are finished or where printing is done in a few colors only. For finer work the direct current motor is especially advantageous.

In general, it may be stated that the conditions in a finishing plant are somewhat unfavorable to motors. High temperatures are experienced, particularly around dry cans and tenters where steam heating is used. Many of the machines are of the slow speed type and belt connections may be unsatisfactory. Many machines are gear driven. Worm and wheel drives have been used but are inefficient. Back geared motors also find application. The silent chain may frequently prove the best arrangement, permitting a wide speed ratio and reasonably high speed motor somewhat apart from the machine. In some cases the motor may be located in a separate room, an arrangement advantageous to the motor.

Because of the high temperatures existing, liberal motor ratings are desirable. To withstand the moisture conditions, special insulation treatment is advisable. In the case of adjustable speed direct current motors it is usually satisfactory to employ an intermittent rated motor even on continuous duty machines because the load at low speed is less than maximum and the motor can carry its rated load continuously at the higher speed as ventilation is improved. Close motoring is not to be encouraged, however, as many factors can appreciably increase the load and a little margin is worth while. The load of most machines requiring speed change is, with a given set of conditions, in the nature of a constant torque and thus increases with the speed. Such factors as weight of cloth, tension of the cloth, per cent moisture or set of rolls may, however, affect materially the basic condition.

THE INQUIRING ENGINEER

The Inquiry

STEAM PRESSURES of 100 to 150 lb. or thereabouts, while they are still used extensively in older plants, are now considered low in the modern industrial and central station plants. Present practice calls for pressures in the neighborhood of 300 lb. Pressures of 600 lb. are now being utilized with apparent success in a few plants, and there are one or two plants being designed for pressures of 1200 lb. In England there is some talk of generating steam at the critical pressure, 3200 lb. per sq. in.

Is all this work on such pressures a case of what might be called "Pressure-Mania" which will be short-lived or will such pressures be common practice in the future?

Replies

H. BOYD BRYDON, Mechanical Engineer,
Byllesby Engineering & Management Corp., Chicago, Ill.

Whatever benefit there is to be derived from the use of pressures of 500, 600 and up to 1200 lb. per sq. in. is a matter for experience to show.

It is purely an economic question, simply that of balancing the higher fixed charges and probable higher operating costs against the coal saving actually achieved. Certainly little, if any, data are available to show that such high pressures will afford financial returns adequate to compensate for the risks involved.

Theoretical heat savings by large increases in pressure are so small and the problems of design, construction and operation so large that plants built to operate at pressures much in excess of 300 lb. per sq. in. must be considered largely as interesting experiments.

There seems to be a tendency to consider the heat expenditure per kilowatt hour output, from the power house to the distributing system as of practically supreme importance, and the fact seems to be lost sight of that in addition to the operating costs the fixed charges on the power house including its proportion of taxes and such bond discounts as may exist are as definite a part of the cost of a kilowatt hour as is the coal.

GEO. W. BACH, General Manager,
Union Iron Works, Erie, Pa.

It is our candid opinion that the present craze for boilers operating at 1200 or 1300 lb. per sq. in. pressure is merely for experimental data that may be derived and that eventually pressures of about 350 lb. with 100 to 200 deg. superheat will be the standard operating pressure for central stations and other efficient power plants. The extreme high pressures mentioned are largely laboratory experiments which will serve, perhaps, to bring out certain features that will be of some benefit to the designing engineer and probably react to establish a somewhat lower pressure for standard practice.

J. W. MACKENZIE, Operating Mechanical Engineer,
Consumers Power Co., Jackson, Mich.

I do not consider this work on higher pressures in any sense a so-called "Pressure-Mania" but consider that it is the natural advance of engineering development.

The development of equipment utilizing these higher pressures and generating equipment to produce these higher steam pressures, I believe, is the direct result of increased fuel cost and cooperative engineering study, not only on the part of engineers themselves but also on the part of large engineering companies.

With the development of evaporators for evaporating the make-up water for boiler feed purposes, all possibility of scale formations in the boilers is eliminated, and I consider that high pressure boilers, 1200 lb. per sq. in. or higher, operated at high rating, are much more safe and reliable than the so-called high pressure of 250 and 300 lb. per sq. in. 10 yr. ago, with the equipment available at that time.

This type of equipment also has an advantage in that it utilizes much smaller piping, and consequently the strain due to repeated expansion and contraction, which undoubtedly has been the cause of many pipe failures in the past, is greatly reduced.

Not only is the development of high pressure equipment desirable from an efficiency standpoint, but it also offers exceptional opportunities in the way of increasing the capacity of plants which are now in operation at locations where the amount of condenser cooling water is limited and is consequently placing a limitation upon the capacity of the plant with the present operating pressure. Under these conditions, the high pressure boilers can be operated in connection with high pressure turbines which will exhaust directly to the plant header, thus increasing both the efficiency and capacity of the plant.

Brooklyn Firm Installs Danish Diesel Engine

ADOLF GOBEL CO. SELECTS OIL ENGINE FOR MEAT PRODUCTS PLANT

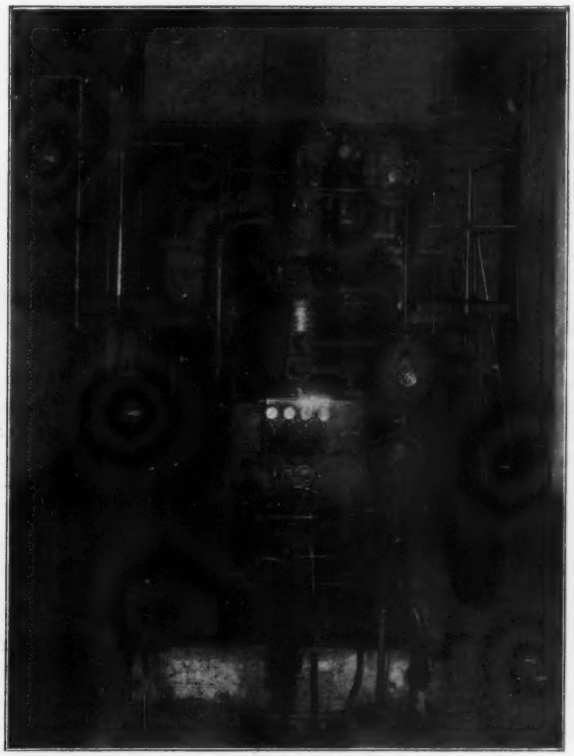
IN MEETING the problem of increased power required by growing business, Adolf Gobel, a leading manufacturer of meat products in the metropolitan area, has adhered to the isolated plant as against the purchase of power, and has installed and recently put in operation a Diesel oil engine instead of additional steam equipment. The decision to do this is of special interest in view of the large number of new buildings and factories in New York City which are now relying on purchased power in view of the uncertain condition of the coal market. Indeed, the power situation has been such in recent years that the smaller factories in big cities have been turning more frequently than ever to central station power rather than risk the supposed hazards of isolated plant operation.

The Gobel power plant is located on Flushing avenue near Wilson avenue, Brooklyn. Room for the addition was provided by tearing down an old house adjacent to the factory. The addition as completed allows space for another unit similar to that which has just been installed.

Prior to the recent installation, the power plant consisted of two 500-hp. oil-fired water-tube boilers, supplying steam for two ammonia compressor sets and two generator sets, one of 100 kw. and one of 75 kw. capacity. The boilers, which also provided steam for cooking in the factory, were loaded up to capacity, so that it would have been necessary to install additional boilers if more steam power had been wanted. It was therefore a question of doing this, of purchasing current from outside, or of employing an internal combustion engine. After careful investigation, it was decided to install an oil engine, and the contract was awarded to the Danish firm of Burmeister & Wain, of Copenhagen, although it is understood that some of the domestic bids were lower than the one submitted by this firm. The award seems to have been based on quickness of delivery and on confidence in the performance of engines turned out by this maker, which are widely used in marine practice and in foreign stationary practice though this is only the second stationary installation by Burmeister & Wain in the United States.

This new unit consists of a three-cylinder, 300-b.hp., four-stroke-cycle, enclosed crankcase engine running at 190 r.p.m., direct-connected to a 200-kw. d.c. generator of the Titan Co., Copenhagen. While the Diesel type is followed in all essential respects, there are variations from American practice to be cited. Most important of these is the oil cooling of pistons, an unusual feature in cylinders of 17-in. diameter with the given speed. As the engine will have to operate continuously for six days per week with heavy loads, this oil cooling will be recognized as very desirable, since it obviates the liability of cracking the pistons. In connection with this point, it is interesting to note that the engine, immediately after installation, was subjected to the factory load for eight days' continuous run without any previous trial.

Oil for the circulating system is drawn from the engine bedplate by a geared pump fixed to the end of the crankshaft, which discharges at 22 lb. gage pressure through a filter to the oil cooler, whence it is distributed through a header on the outside of the crankcase to the main bearings. From these it passes through the hollow crankshaft to the connecting rods, and up these to the crossheads and into the pistons. After serving for cooling these, it is returned through telescopic pipes to the bedplate, a branch connection being provided for each cylinder to a funnel outside the crankcase, where the temperature may be taken and oil samples secured as desired. For starting, a hand oil pump is furnished to prime the oil circulating system.



THREE-CYLINDER, 300-B.HP., FOUR-CYCLE DANISH DIESEL ENGINE INSTALLED BY ADOLF GOBEL CO.

Cylinder lubrication is accomplished by a special sight feed pressure lubricator, which is understood to be controlled by the Vacuum Oil Co. for whom it is manufactured by a Copenhagen firm. It is stated that this device has been found extremely satisfactory in European practice and that its introduction into this country is anticipated.

For the storage of fuel oil, tank capacity to the extent of 12,000 gal. is available. The oil level is indicated by a Pneumercator gage. From the storage tanks, delivery is made to a daily supply tank above the engine level, and from this through two strainer tanks to the fuel injection pump, which serves all three cylinders, with a distributor on each cylinder. Regulation of this pump is controlled by the governor, varying the fuel supply according to the momentary load require-

ments. A device operated by hand lever from the floor level is provided for cutting off the fuel oil supply instantaneously in case of emergency.

Air, starting, fuel and exhaust valves are located in the cylinder head and are driven through intervening mechanism from the crankshaft. Of particular interest is the mushroom spray type of fuel valve, opening inward with an annular opening. This design was developed by Burmeister & Wain and has been employed by them as a standard type.

Compressed air for fuel injection is supplied by a three-stage compressor driven from the crankshaft. Air for starting is stored in two "air bottles," while a third of smaller size is used for supplying air needed for injection.

Cooling water from the city mains is put through the following cycle: it is first used in the oil cooler and then for the air compressor and air coolers, from which it is run through the jackets of cylinders and cylinder heads to the exhaust manifold. From this point it goes to a hotwell to be used for boiler feed in the steam end of the plant, thereby conserving in part the heat losses from several sources in the oil engine.

The Origination of an Engineer

By H. W. Rose

I HAVE READ with pleasure the article "Should Engineers Specialize," by Jack L. Ball, on page 740 of the July 15 issue of Power Plant Engineering. Mr. Ball's logic displayed, is not only worthy of consideration and interest to all progressive men in this profession, but, if it is as earnestly received as he has attempted to convey to others, his opinion upon specializing will be, I am sure, quite a step in the line of advancement.

I am tempted, however, to express my views upon the subject. Mr. Ball loses sight of the fact from a statistical census of figures compiling the engineering force of the world, that the majority of engineers in the field today are in it because circumstances in the seeking of employment offered them the opportunity in some branch of power plant work. It may have been as a helper in the boiler room, or it may have been as an oiler that this young man had to secure employment; the power plant offered him an opportunity and with a strong back coupled with a limited education, his enthusiasm is aroused. Association with his superiors, and a little encouragement with respect to showing him the advantages of using the proper technical libraries within his reach will in the majority of cases, enable such men to make good, go to the front and stick. We can readily see that the thing that has lured men into the various branches of the mechanical world has been the assured large salaries as a rewarding goal combined with social and professional surroundings which but few professions will offer.

In any institution, not only the chief and assistant chief engineers in charge, but the manager as well, should be thoroughly master of every working device and its mechanical details throughout. If they are not, we cannot expect the most efficient results and success that the business deserves.

Specializing, I admit, is a time saver when it hinges upon the viewpoint of the installing of a switchboard or some other equipment about the plant and we usually have the factory to send us a man suitable for the equipment to be installed, which is generally at a price of $15 a day and nothing is thought of it. This is so because the engineer or assistant, as a rule, is too preoccupied with matters relating to the general routine of affairs to give his entire time to this special piece of work. If they were not qualified, however, in a general way, the same as a specialist, it would only be a question of time when adjustments and minor troubles which generally arise for correction whereby the institution would find their mechanical affairs at some time in a very critical condition should there not be at hand a master of the situation.

I concede it to be a fact that it is a poor rule that does not work both ways and that conditions arising from the uncontrollable guidance in a man's career causes circumstances to arise whereby he accepts the opportunities as they present themselves, and those who have become successful have done so by mastering fully and thoroughly each plane to which that they have succeeded, and the old proverb that engineers, regardless of brains, are not made but are born, is truly to be reckoned with. When we observe the successful one and analyze his career, the chart clearly indicates a few simple facts; the crowning one in every case is his love for his profession, honesty with his work and everlasting persistency in his attention to his duties and responsibilities.

Ten Rules for Making a Failure of Engineering

By James E. Noble

(1) Do not study the theory of engineering.

(2) Do not ask advice when you have a difficult problem to solve and you are doubtful about the answer.

(3) Never be on the job before the regular starting time or after stop time.

(4) By no means give any information to a fellow worker in the plant if he tells you he is puzzled and asks you to help him.

(5) Never wear a smile or give a pleasant word to anyone in the plant.

(6) Never subscribe for or read an engineering journal.

(7) Knock every plan that has for its object the education of the engineer about things engineering.

(8) Never study the selling section of trade journals for therein you would learn about, and see, illustrations of modern equipment.

(9) Do not inspect the boilers in the plant or make repairs until conditions force you to do so.

(10) Only work at engineering for the dollars you can get out of it, faithfully endeavor to take no pleasure or interest in doing the work.

Honestly follow out the foregoing rules and you will certainly succeed in being a failure as an engineer.

Boiler inspection and insurance companies' reports show that about half of the boilers inspected by them are defective due to burned plates, leakage at joints, leakage around tubes, defective tubes and internal corrosion and scale. All of these defects can be traced directly to the feed water.

Development of High Pressure Steam Boilers*

PRESENT DAY FACTORS OF SAFETY NEED NOT BE MATERIALLY REDUCED UNLESS TEMPERATURES EXCEED 750 DEG. F. BY D. S. JACOBUS†

JACOB PERKINS was a pioneer in the use of high pressure steam. In 1822, over 100 yr. ago, he made an apparatus in which water was heated under a high pressure in a generator kept full of water by a force pump and only a small quantity of the highly heated water was allowed to escape at a time into a tube, where it flashed into steam and passed on to an engine. His generator of 1824 is described in the following way in a book entitled, "History and Progress of the Steam Engine," by Elijah Galloway, published in London in 1830:

"The boilers, or steam generators, as they are called, are in this case very thick cast-iron bars, 5 in. square, with circular holes perforated longitudinally through them of 1½-in. diameter, a transverse section of which is exhibited in the figure. They are arranged in three tiers and are of sufficient length to lie across the furnace, and to pass through the opposite walls, where their extremities are connected together so as to form one continuous vessel. By the operation of the forcing pump, water is continually injected into the two upper tiers of generators, so as to keep them always full, and under the pressure of a heavily loaded valve. The lowest tier of generators contains no water, but is kept at a temperature of about 1000 deg. F.

"At each stroke of the engine, a certain quantity of water, heated, to about 700 deg. or 800 deg. F., is discharged into the valve box communicating with the lowest tier, wherein the water flashes into steam; the steam thus formed passes successively through every pipe in the lowermost range, which is exposed to the strongest action of the fire, before it enters, by a short tube, a safety chamber for the supply to the engine, to which it is conveyed by a pipe. A loaded valve is provided to relieve the pressure should the chamber become overcharged with steam."

Heating the water to 700 or 800 deg. F. would involve operating at the critical pressure of, say, 3000 lb. per sq. in.

The late Frederick Sargent talked with me on a number of occasions in regard to the form of boilers that might be developed to meet the demand of increasing pressures. This led to the Babcock & Wilcox Co. deciding that it would be advantageous to make experiments on a boiler built along entirely different lines from those it was constructing with the idea of determining the possibilities. This resulted in the design and construction of a boiler between 7 and 8 yr. ago in which there was a forced circulation and which had no steam and water drum. The boiler was purposely made of a form in which it was felt there might be certain difficulties in order to search out the principles involved in such boilers. The arrangement of the boiler in the form in which most of the tests were made is shown in Fig. 1. In the first tests the water was fed into the cross box most remote from the fire, passed in series through the loops from one cross box to the next and finally left in a superheated state from the last cross box. But few tests were made on this form and the boiler was changed by placing the separating tank shown dotted in Fig. 1 between the economizer and boiler part and the set of loops nearest the fire which formed the superheater. The boiler was fed in the same way as in the first form and the steam generated, together with some contained water, passed into the separator. The loops were constructed of 2-in. tubes and the straight portions of the loops were fitted with cores. The water was maintained at a given height in the separating tank by regulating the rate of supply of the feed water and at the same time a small amount of water was continually bled from the separating tank

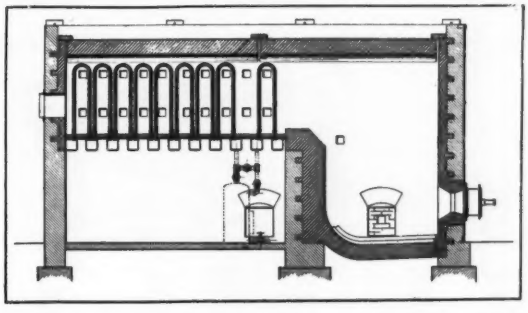


FIG. 1. EXPERIMENTAL BOILER OF THE SERIES TYPE

and returned to the feed water. This insured the passage of a certain amount of water at all times through the economizer and boiler element. From the separating tank the steam was passed to the superheater located next to the fire. The name "Series Boiler" was applied to the apparatus.

It was first intended to place boiler surface ahead of the superheater so that the hot gases from the furnace could pass first over boiler surface, then over the superheater and thence over the boiler and economizer surface. In order to simplify the apparatus the boiler surface was not placed ahead of the superheating surface and doors were provided in the setting for tempering the gases from the oil fired furnace to a point where they would be at a low enough temperature to avoid burning the superheater. After the cores had been adjusted to the size finally used it was found unnecessary to admit air to prevent the superheater from being burned out even though the oil furnace was at a high temperature. The superheater tubes became coated with black oxide on the outside, but they did not burn out nor was there any trouble through leakage throughout the tests, although the superheater might have failed eventually had the boiler been run for a longer time. The boiler was operated at a maximum capacity of about 425 per cent of rating based on the entire amount of heating surface of the economizer, boiler and superheater. The surface was not arranged in a way to give efficient results, the object of the tests being to determine the features of circulation and the practicability of operating a boiler of the sort.

In operating a series boiler care must be taken in starting up to maintain a circulation of water or steam

*Paper delivered before Annual Convention, Iron and Steel Electrical Engineers, Buffalo, Sept. 24-28.

†Advisory Engineer, Babcock & Wilcox Co., New York, N. Y.

through the boiler. This would necessitate the installation of special arrangements in a power plant especially if the heat imparted to the boiler in the starting up is returned to the system. Again, it is difficult to operate a boiler of the sort under fluctuating loads and in any event the feed water pumping system must have 100 per cent reliability.

It was therefore decided to build a series boiler to be used in combination with a relatively small boiler having a steam and water drum. The combined unit shown in Fig. 2 was therefore constructed.

This consisted of a boiler with 2-in. tubes having a steam and water drum and a combined boiler and economizer with 1-in. tubes in which the heating surface was 3.7 times the heating surface of the boiler having the steam and water drum. The unit was a comparatively small one, having 187 sq. ft. of tube surface of the boiler with the steam and water drum exposed to the hot gases, 51 sq. ft. of superheater surface and 685 sq. ft.

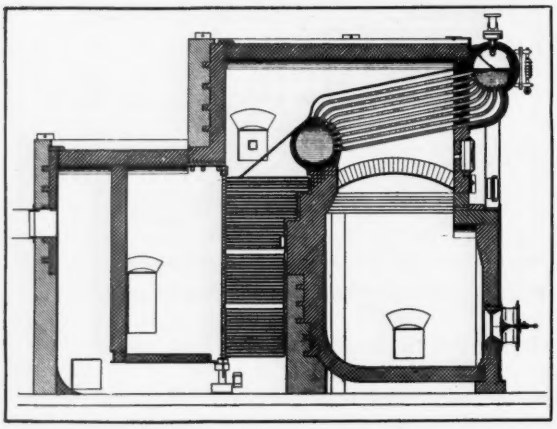


FIG. 2. A LATER UNIT OF THE SERIES TYPE

of boiler and economizer surface in the section made of 1-in. tubes, or 923 sq. ft. of heating surface in all. The boiler was fired with oil fuel with a mechanical atomizing burner and operated at 600-lb. gage pressure. A connection fitted with a valve was run from the steam and water drum to the lowermost part of the series boiler and this connection was left open in starting up the boiler so as to provide a local circulation. The unit was run at times at over 500 per cent of rating, based on the total boiler and economizer surface and all parts were found to operate in an entirely satisfactory way. The percentage of rating at which the boiler with 2-in. tubes having the steam and water drum was operated in the high capacity tests was about 1500 per cent.

Modern High Pressure Boilers

We are building boilers for 1200-lb. working pressure with wrought steel economizers for power plant service of the general form shown in Fig. 3, which is illustrative only as certain features of the tube arrangement may be changed. In developing this boiler, we had before us the results secured with the use of 1-in. tubes in the great number of our White-Forster marine boilers for destroyer service and the results of the experiments with the series boiler. A great number of different arrangements were laid out and considered and the one finally adopted was that shown in Fig. 3, which approaches very closely to a standard Babcock & Wilcox boiler. In this boiler the steam generating tubes are 2 in. in diameter, which is a convenient size for internal cleaning, whereas it is difficult, if not impossible, properly to clean tubes, say, 1 in. diameter and smaller. The steam and water drum, which is 48 in. internal diameter of forged seamless steel construction provides a reserve water capacity, making it easy to operate the boiler under all sets of conditions, such as in starting up and under variable loads and making it unnecessary to provide pumps having 100 per cent reliability, such as would be necessary for a series boiler. The tubes are arranged so that they can be thoroughly cleaned on the outside from between the diagonal lanes. The feed water from the economizer passes directly into the boiler, which makes it necessary to build the economizer for a somewhat higher pressure than the boiler. The economizer is made up of 2-in. seamless steel tubes expanded into forged steel boxes. The boxes are spaced apart to allow the removal and replacement of the economizer tubes from between the boxes with the tubes at an angle, which allows the tubes to be removed and replaced with a relatively narrow aisle width. The ends of the horizontal circulating tubes of the boiler are bent so that they enter the drum in circumferential lines which are twice as far apart as the distance between the horizontal circulating tubes where they enter the headers. This greatly increases the efficiency of the ligaments between the tube holes. There are two circulating tubes running from the top of each uptake header to the steam and water drum. The boilers are built to meet the requirements of the A. S. M. E. Boiler Code. Certain features of the forged steel drum are not covered in the A. S. M. E. Code, but the general character of the steel in the drum will conform closely to that specified in the A. S. M. E. Code for boiler plate and the maximum allowable stress is taken at 11,000 lb. per sq. in., thereby corresponding to the figure specified in the code.

These boilers built for 1200-lb. working pressure will be supplied with individual steam turbines. It is the idea eventually to generate all of the steam for a power plant with high pressure units of the sort and after passing the steam through several of the high pressure steam turbines to pass the exhaust steam from these high pressure steam turbines to a main steam turbine. The steam supplied to the high pressure steam turbines is superheated to a total temperature of, say, 725 deg. F., by primary superheaters. The exhaust steam from each individual high pressure steam turbine is returned to a secondary superheater placed within the high pressure boiler setting at a pressure of, say, 300 lb. above the atmosphere and is resuperheated to a temperature of, say, 725 deg. F. and supplied to the main steam turbine. The individual high pressure steam turbines therefore serve to reduce the pressure of the steam from the initial pressure of 1200 lb. to that used at the main steam turbine. With an economical main steam turbine operated with the exhaust steam from the high pressure steam turbines, the amount of power generated by the high pressure steam turbines would be 20 to 25 per cent of that generated by the main steam turbine. Should the main steam turbine be run at a lower pressure than 300 lb. and at a lower temperature than 725 deg. F., the gain through using the high pressure would be increased and might reach, say, 30 per cent or more.

There is a possibility, therefore, of revamping present power stations and considerably increasing their efficiency through using the high pressure units with individual steam turbines and exhausting the steam into the present steam mains. In order to warrant the additional investment necessary for installing high pressure boilers in an old plant it would be necessary to have a very steady load, or what is known as a "base load condition." The investment would not be warranted under present conditions for a widely fluctuating load.

In place of using individual high pressure steam turbines for each boiler, the high pressure steam from a number of boilers could be used for larger high pressure turbines. Experience alone can demonstrate which system will be best and no one can say what plan will be adopted in the future in the effort to secure higher and higher efficiencies. There will no doubt be difficulties that cannot be foreseen to be worked out and those who are pioneers in installing high pressure units of the sort should be commended for their willingness to spend the time and money that will be necessary in the development.

Factors Affecting Design

If it were possible to maintain absolutely tight surface condensers it would be unnecessary to clean the interior of the boiler tubes and the problem of designing high pressure boilers for power plant service would be greatly simplified. Under present conditions there is always a chance of leakage at the condensers, either at the tube ends or through the cracking or corrosion of the tubes, and this necessitates arranging the boiler so that it can be cleaned on the inside. Tight condensers and the use of a closed system would also overcome any trouble through corrosion due to oxygen in the feed water on the interior of the economizer and boilers. The fact remains, however, that leakage in condensers has not as yet been overcome and the problem of both cleaning the interior of the tubes and of removing any excess oxygen from the feed water must be faced in all cases.

Effects of temperature on the lowering of the elastic limit of steel has been referred to by engineers as something that might give trouble in a high pressure steam boiler. At a temperature of about 750 deg. F. the elastic limit may drop to half that obtained at ordinary room temperatures and it is important that the effect of this falling off be understood. The temperature of the saturated steam corresponding to 1200 lb. pressure is somewhat less than 570 deg. F., and at this temperature the strength of the steel is higher than at ordinary room temperatures and the elastic limit is about the same or only slightly lower, so there need be no apprehension with respect to the boiler proper. The only part that is affected through being brought to a temperature that would cause any material difference in the strength or the elastic limit of the steel is the superheater. Of all parts of a boiler the superheater is the safest as far as its liability to injure anyone or to cause property damage is concerned, as the worst that might happen in case the superheater became overheated would be to burn out or blow out some of the tubes, and this would not ordinarily result in any damage other than to the superheater itself.

Effects of rising temperatures are first to increase the tensile strength of steel from, say, 10 to 20 per cent, and afterwards to decrease it and at 700 deg. F. the tensile strength is about the same as at ordinary room temperatures. At 750 deg. the tensile strength falls off, say, 10 per cent below what it is at ordinary temperature, and the elastic limit is about one-half what it is at ordinary room temperatures. In a complicated structure used under pressure at 750 deg. F., the falling off in the elastic limit would result in a liability for leakage and in such a structure it might be well to use a factor of more than five based on the tensile strength. In a structure like a superheater, however, there would seem to be no necessity of providing a factor of safety of more than five based on the tensile strength. We have become so accustomed to the use of relatively high factors of safety in boiler construction to those used in some other lines that we are apt to overdo matters to make sure we are on the safe side. When one considers the relatively low factors used in the design of large

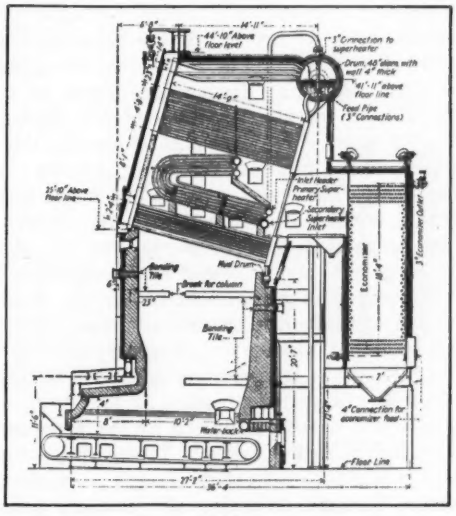


FIG. 3. MODERN 1200-LB. B. & W. BOILER

guns and for torpedo tubes carrying very high pressures one feels a great deal safer when it comes to boiler design. Again, in the work we have done in designing and building oil stills and tanks for use at high pressures and at temperatures of 825 deg. F., we made a careful study of the falling off of strength and elastic limit and of the practice in still design that has been found to give safe results and all this makes us more confident in feeling that the factors of safety we are using in boiler and superheater design are ample.

Methods of Attemperating Superheated Steam

As superheated steam of higher and higher temperatures is being used in power plants the time is approaching when it may be necessary to provide some automatic means for preventing the temperature exceeding a certain figure. It has been the general practice to run at a temperature which can be exceeded for a time without giving trouble. The Babcock & Wilcox Co. made experiments over 10 yr. ago to develop an apparatus for attemperating superheated steam and maintaining the temperature at a given figure, provided the initial temperature of the steam entering the attemperator was at a somewhat higher temperature than the steam discharged. It was found entirely practicable to hold the temperature within a range of, say, 5 or 6

deg. F. between the highest and lowest points by spraying a regulated amount of water into the superheated steam. The apparatus consisted of a vessel containing water placed in the exit pipe conducting the superheated steam away from the attemperator. There was a definite pressure generated in the vessel for each particular temperature through boiling the contained water, and this pressure acted on a diaphragm and actuated an apparatus for admitting more or less water to the superheated steam. The temperature of superheated steam that could be handled in this way was limited to, say, 650 deg. F. For higher temperature than this, it was proposed to use mercury in place of water in the vessel. Shortly after experimenting with the attemperating device the idea was applied to an independently fired superheater as a superheat limiting device where, on the temperature rising to a given point, doors were opened in the setting for admitting cold air. This arrangement proved to be entirely reliable through trials made every 24 hr. where the temperature was purposely raised to the point for which the apparatus was set. An interesting feature developed as it was found possible to operate the independently fired superheaters much more closely through observing the pressure in the vessel containing the water than by reading a thermometer. The vessel consisted of a coil having a considerable surface in contact with the superheated steam in proportion to its volume and an attached pressure gage indicated changes in temperature much more effectively than a thermometer, as the change in pressure due to the boiling of the water was greater than the corresponding change in the temperature. For example, raising the temperature from 490 to 500 deg. F. resulted in raising the pressure 62 lb. per sq. in., so that there was a change indicated by the pressure gage of about 6 lb. for each 1 deg. F. It was found that the superheater could be operated at such a constant exit temperature through observing the pressure gage that a recording thermometer placed on the outlet gave practically constant readings.

An apparatus of the sort could be used either for attemperating the steam and holding it at a given temperature, or it could be used as a limiting device to reduce the superheat in an emergency without attempting to maintain the temperature of the steam at a given figure.

In the latest boilers for high pressure and high temperature superheated steam built by the Babcock & Wilcox Co., the superheater is placed above a series of tubes in a drop-leg and below the main body of tubes of the boiler. A superheater properly arranged in this position in a properly designed boiler gives a more constant degree of superheat at different ratings than if placed in the ordinary position above the boiler tubes and permits a higher degree of superheat to be obtained with a given amount of superheating surface, and for the temperature of superheated steam now employed the superheat obtained with a superheater of the sort is near enough constant for use without an attemperating device.

There is but little gain in the economy in increasing the steam pressure to a higher point than 350 lb. per sq. in. without interstage heating of the steam; that is, the steam from one stage of the turbine must be withdrawn from the turbine, resuperheated and returned to the following stage of the steam turbine. Interstage heating necessarily involves additional complication and added expense and the possible difficulties in operation due to the additional complication have an important bearing on the use of the higher steam pressures.

Plan to Utilize Colorado River

The problem of developing the waters of the Colorado River for irrigation and power and to lessen danger from floods in Imperial Valley, is arousing great general interest. The first thing needed in connection with any such development is a survey, but a 300-mile stretch of this 1500-mile river, including the ruggedest part of the Grand Canyon, has not yet been surveyed in any detail. The surveying and mapping of this stretch, which includes the dangerous gorges of the Marble and Grand Canyons, will be started on Aug. 1, as was announced at the Department of the Interior today. This part of the river's course, which is crowded with bad rapids that swirl between steep rock banks, has been traversed on only six previous occasions. It was first explored in 1869 by Major W. Powell, later Director of the Geological Survey. The present party of engineers and geologists of the Geological Survey will make a trip by boat from Lees Ferry through the canyons to the mouth of the Virgin River, through the canyons to the mouth of the Virgin River, in Arizona, a distance of about 300 miles, and will make records of the slope of this entire stretch of the river and of the topography.

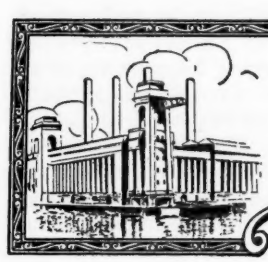
The Colorado, one of the great rivers of the country, is often called the Nile of America. It drains nearly 250,000 square miles, an area equal to that of the Atlantic Coast from Maine to Georgia. The highest points in its basin are the peaks of the Continental Divide, which stand more than 14,000 feet above sea level, and a part of its water finds its way into Salton Sea, in southern California, which lies more than 250 feet below sea level.

Stretches aggregating about 1200 miles on the Colorado and its principal fork, Green River, and several hundred miles on other tributaries have already been surveyed and mapped by the Geological Survey, and these stretches, together with the 300-mile stretch to be surveyed this year, extend continuously from the town of Green River, Wyo., on Green River, and from Grand Junction, Colo., on Colorado River, to the Mexican boundary.

Detailed examinations are to be made of possible dam sites, which will be considered from both the engineers' and the geologists' point of view. Four boats of special type have been constructed for this work.

Damper Calibration

IT IS ALWAYS advisable to calibrate a damper because its resistance to gas flow is not in direct proportion to the amount that it is open. To calibrate a damper, connect a differential draft gage so that it will show the drop in pressure past the damper. Place the damper in its closed position and then gradually open it until the effect is noticeable on the draft gage. Mark this point and then continue to open the damper until no further change is noticeable. That point should also be marked. The working range of the damper is then between the two points just mentioned.



LETTERS DIRECT FROM THE PLANT

Solution to Wheatstone Bridge Problem

I OFFER herewith an arithmetical solution of that oft repeated problem of finding the joint resistance of five resistances connected in the form of a Wheatstone bridge.

This problem, in its general form, seems to keep popping up, at irregular intervals, as a catch problem, but it need no longer be considered as such, by readers of this paper, for here is a solution which makes use of nothing higher than common fractions.

Problem: Let AB, AC, BD, CD, BC, be five resistances connected as shown in diagram.

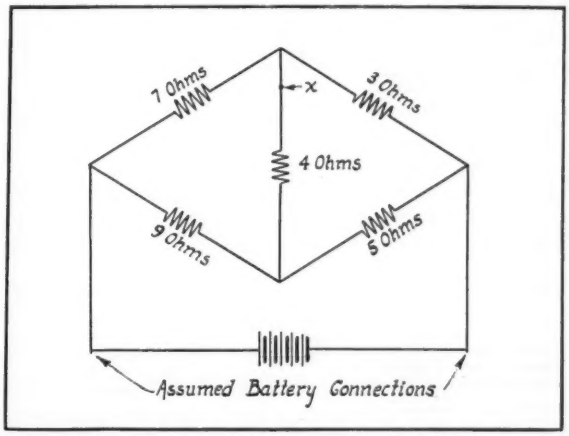
Required: To find the joint resistance offered to the flow of an electric current from A to D.

Solution: Suppose a battery connected with positive pole to A and negative to D. The direction of the current through BC may be determined by supposing the circuit opened at some point as x, and a difference of potential of one volt maintained across A to D. The current through ABD will be 1/10 amp., or voltage divided by resistance, and the drop of potential from A to B is 3/10 v., or current multiplied by resistance. The potential at B, then, is 3/10 v. lower than at A. Through the branch ACD the current will be 1/14 amp. and the drop from A to C 5/14 v., and the potential at C is 5/14 v. lower than at A. But at B the potential was found to be 3/10 lower than A, then C is lower than B by an amount equal to 5/14 minus 3/10 or 4/70. Therefore with the circuit closed at x and under the assumed conditions current would flow from B to C.

With the foregoing direction of current in mind, assume a voltage from A to D just sufficient to cause 1 amp. to flow from B to C; the potential difference between B and C is then 4 v. This 1 amp. through BC must also pass through AB, causing a drop of 3 v., and through CD in which the drop is 9 v. Now suppose the circuit again opened at x. The interruption of this 1 amp. through BC makes the 3 v. which was being dropped in AB, now available to produce current through ABD, which will cause a flow of 3/10 amp. Considering AB alone, there is a loss of 1 amp., which flowed through BC and a gain of 3/10 amp. now going through BD, which gives a resultant loss of 7/10 amp., and a consequent rise of potential at the point of B of 2 1/10 v., which is found by multiplying the current by resistance, or 7/10 by 3, according to Ohm's law. Now considering the lower branch, it is found that the interruption of the circuit at x makes the 9 v. previously dropped in CD available to produce current through ACD. This produces 9/14 amp., which, flowing through AC, causes a drop of 9/14 times 5, 3 3/14 v.

Summing up the potential across BC, there was 4 v. with the circuit closed at x while with it opened there was a rise of 2 1/10 v. at B and a lowering at C of 3 3/14 v., making an ultimate voltage across from B to C of 4 plus 2 1/10 plus 3 3/14 equals 9 22/70 v.

It was shown above that 1 v. from A to D produced a potential across from B to C of 4/70 v.; then it follows that to produce 9 22/70 v., there must be maintained 9 22/70 divided by 4/70 or 163 v. from A to D. This was the voltage necessary to cause 1 amp. to flow through BC when the circuit is closed at x.



THE PROBLEM IS TO FIND THE JOINT RESISTANCE OF THIS CIRCUIT

This 1 amp. through AB, BC, and CD will cause a drop of 3 v. in AB, leaving 160 v. to produce current in ABD, which results in 16 amp. In CD this 1 amp. causes a drop of 9 v. leaving 154 v., which will produce 11 amp. in ACD.

Summing up these currents: There is 1 amp. through ABCD, 16 amp. through ABD, and 11 amp. through ACD, making a total of 28 amp., produced by 163 v. through the joint resistance of these five resistances.

Joint resistance, therefore, equals 163 divided by 28, or 5 23/28 ohms.

Loma Linda, Calif. J. M. Row.

Preserving Pipe Fittings

WHEN CLOSE nipples are removed from pipe fittings there is always more or less damage done to the nipple by the wrench. This, in many cases, forces the nipple out of round to such an extent that it will not again make a tight joint and will have to be thrown away.

I have always preserved these nipples by threading on the coupling before using the wrench. The fitting acts as a protector to prevent the nipple being compressed to an egg shape by the pipe wrench. The advan-

tage of this method will be appreciated by the man who has had the misfortune of destroying his last close nipple in this way.

When making or rethreading a close nipple, it will be found of great advantage to have a piece of scrap pipe threaded on one end nearly the full length of the coupling. With the pipe held in the vise, screw the close nipple into the coupling as far as it will go by hand and then screw the coupling onto the pipe until the nipple is hard against the end of the pipe.

This serves as a lock nut and prevents the nipple being turned tight in the coupling.

Winnipeg, Man. C. Rye.

Convenient Record for the Pulley Store Room

While the average engineer is much averse to keeping "books" or records, still it is the writer's experience that if he finds that he can save time or effort by so doing he will do it. One of the greatest time savers we have used in this direction is a large card which we keep hanging up on the door of the room in which we store all our odds and ends of pulleys.

Before keeping this record, whenever we needed a pulley it was necessary to go into the room with a rule and measure up various pulleys for bore, diameter, etc., and it usually involved almost an hour's time before we got what we wanted. On the card we now keep listed all the pulleys we have in stock, so that a glance at the card shows us what we have, or what we do not have;

PULLEY STOCK

DIAM.	FACE	BORE	K.S.	DATE PUT IN STOCK	OBTAINED FROM WHERE	USED	FOR WHAT

STOCK CARD FOR PULLEYS

and since it requires but little effort to keep the record going after it is once started, we have found it to be a great convenience and time saver. In fact, we have found it so handy and so easily workable that we have extended the same scheme to other odds and ends, such as shafting, hangers, belts, etc.

Philadelphia, Pa. M. A. Saller.

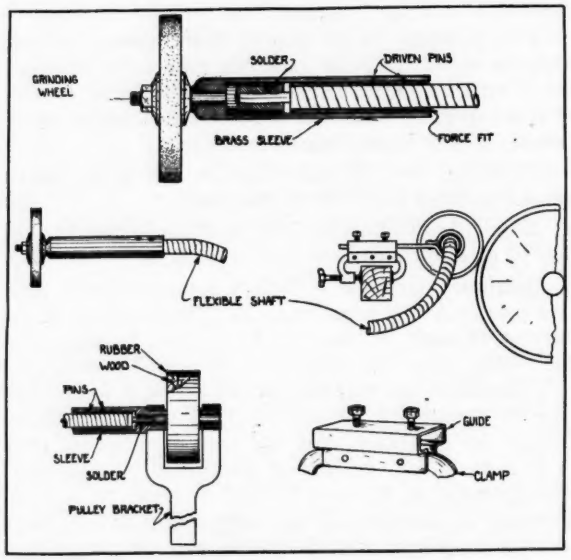
Grinding with Flexible Shaft Has Many Uses

Herewith is illustrated a special construction for a grinder, which can be driven from almost any revolving part. It is fitted with a clamp fastener, flexible shaft and a small grinding wheel.

This fixture extends the service of the grinder to almost any condition of use. It is portable and is readily driven from the rim of an engine flywheel or from the rim of a pulley on the line shaft of the shop.

The flexible shaft used is a 5-ft. or longer length of the wire type of flexible shafting. Heavy speedometer shafting is also of use for this fixture; however, the usual types are not so substantial as the wire wound shaft. A simple steel plate bracket supports the drive pulley, to which the shaft is attached. The drive pulley is a circular block of any hard wood faced with rubber. A band cut from an inner tube, that is, in cross section, is good for rubber facing, and is simply cemented to the wood.

The opposite end of the shaft is fitted with a brass sleeve forming the handle and at the same time a bearing for the wheel. The clamp is a heavy "C" type of machinist's clamp, with a riveted guide on the back flange. The pulley bracket is adjustably secured in this



PORTABLE FLEXIBLE GRINDING FIXTURE MAY BE DRIVEN FROM ANY REVOLVING PART

guide, set screws being provided for retaining the pulley bracket.

By means of the clamp, the drive pulley is secured adjacent to any rotating part, the pulley is placed against the rim or face of the driving part and the emery wheel is ready for any form of grinding which can be done by hand.

Washington, D. C. G. A. Luers.

Painting Boiler Prevents Corrosion

Some time ago I had a lot of trouble with corrosion in our boilers which the boiler inspector said was caused by the water we used which was heated to a temperature of 180 deg. F. in a closed heater. The water was taken from Lake Ontario. The tubes were corroded along their entire length principally on top and in spots from 1 to 2 in. apart. We had tried out several different compounds as well as caustic soda and soda ash, etc., without result. As the trouble continued, the inspector suggested that we paint the inside of the boiler to prevent the water coming into direct contact with the boiler. This was done and although it was difficult to reach some parts, the job was finished at last and the corrosion was checked. We had no more trouble for a year; slight cor-

rosion then showed but another paint application stopped it.

In applying the paint, the boiler was carefully cleaned and dried and then given a coating of boiled oil and Portland cement mixed thick enough to be put on with a stiff brush. This coat was allowed to dry for three or four days and then another coat, consisting of one part graphite and three parts Portland cement, thinned with boiled oil, was applied.

This coating is effective in preventing corrosion and is not affected by the repeated expansion and contraction of the boiler shell or tubes.

Toronto, Ont. JAMES E. NOBLE.

Handy Circular Tank Chart

HERE IS a chart that will be found useful for determining the number of barrels in a circular tank of almost any diameter.

Run a straight line across the chart connecting the height of the tank with its diameter, and the intersection

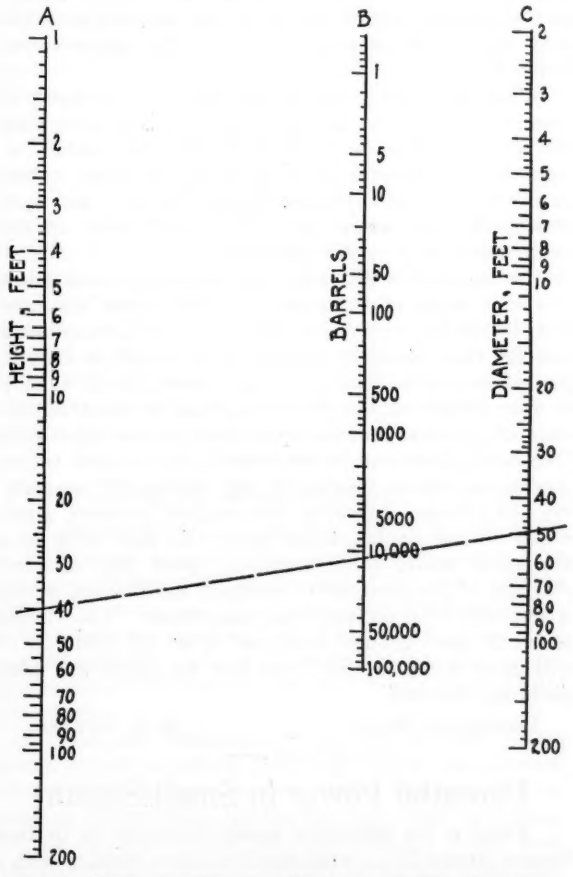


CHART GIVES NUMBER OF BARRELS IN CIRCULAR TANK

with the middle column (column B) gives the number of barrels instantly.

For example, if we have a tank 40 ft. in height and 50 ft. in diameter, what is its capacity? The dotted line drawn across the chart shows how it is done. Connect the 40, column A, with the 50 ft., column C, and the intersection with column B gives the answer as—about 12,000 bbl.

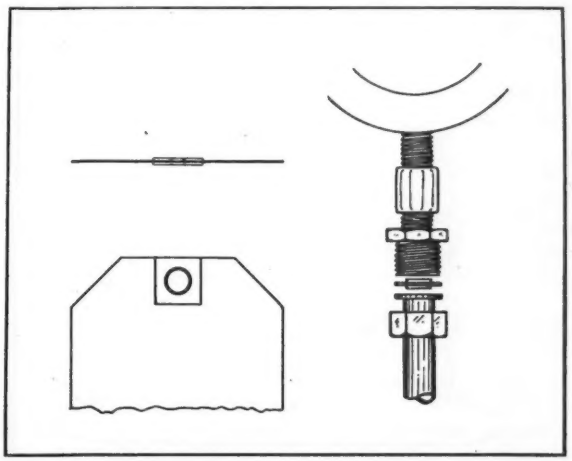
In case it is desired to know how much is in a given tank at a given time, column A represents the depth of the liquid in ft. and column C the diameter, as before. The figures in column B then represent the number of barrels in the tank.

The chart may also be used backwards for determining the height to which a given tank should be built or the diameter it should be given for a capacity of any number of barrels. Or, it may be used for determining the height to which a tank should be built where the capacity and diameter are both known. In other words, where any two of the factors are known, the third is easily found by means of this chart.

W. F. SCHAPHORST.

Emergency Gasket from a Shipping Tag

IN MANY instances, a soft gasket needs to be temporarily put in flat joints of the fittings of gages, governors, etc. It is a difficult thing to cut rubber or heavier gasket material to sizes as small as some of them need to be. The accompanying sketch shows how a good soft gasket of oiled or compressed paper can be secured from the eye hole of an ordinary shipping tag.



USE OF SHIPPING TAG EYELET AS A GASKET FOUND CONVENIENT IN AN EMERGENCY

The three layers of tough compressed paper with the brass eye make an ideal small emergency gasket. The writer has resorted to this a number of times in a pinch, and the "kink" might help someone else.

F. W. B.

Ordering and Making Repairs

AMONG MY duties, I have charge of 14 steam traps, eight of one size and make but no two of them alike as far as discs and seats are concerned. When I order discs and seats for replacement, I am always requested to send the defective parts along to be duplicated.

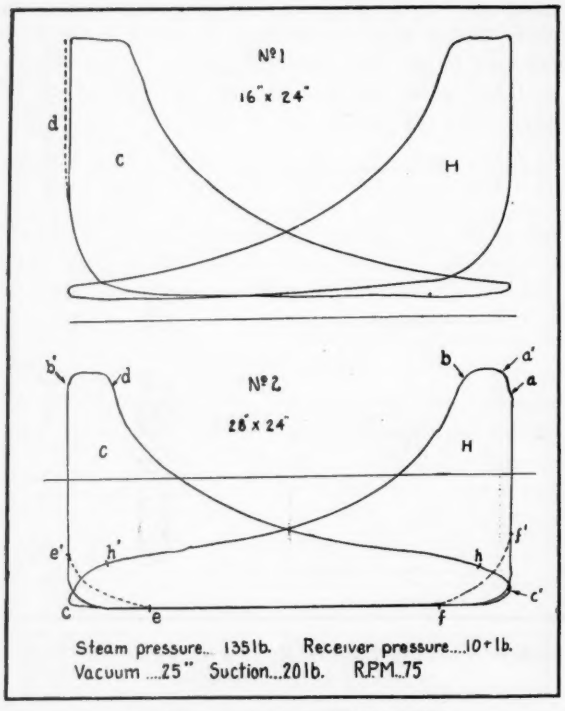
This means a change of traps and a lot of trouble. I often wonder why manufacturers do not standardize their parts to relieve the engineer of this troublesome task. Then one could order repair parts by number.

OPERATING ENGINEER.

PROBLEMS IN OPERATING POWER EQUIPMENT

Should Well Enough Be Left Alone?

REPLYING to G. L. B.'s inquiry on page 846 of the Aug. 15 issue of Power Plant Engineering, the cards do not show much misadjustment, but considerable wear on the valve mechanism. The high pressure card is good, but the tail plates on the latches should be replaced to get a sharper point of cutoff. On the crank end diagram admission is a trifle late; the diagram



AMENDED CORLISS ENGINE CARDS

should follow more closely the dotted line (d). This condition is caused by the latch block and latch plate being worn down probably about 1/32 in. each. If it is possible, they should be turned around to new edge or replaced. Looseness in the ends of the steam rods where they connect to the wrist plate should be taken up. This would cause the valve to open a trifle earlier.

Neglect to replace or turn the case-hardened latch edges which is so necessary for safe, economical operation, is indicated on the low pressure card. The contour of the low pressure diagram at A shows that the head end steam valve does not open full port opening until the piston has started on its return stroke and the pencil run up to A′ where it follows the steam line to b, the point of cutoff, which is round due to wear of the tail plate on the latch and the roller or tripping cam, which does not trip sharply enough. It appears from the expansion line, and terminal pressure at release h′, which is high, that the steam valves must leak some or the dashpots do not close quickly, which allows steam to enter the cylinder after cutoff occurs. The sharp point, C, shows this exhaust radius rod may have a worn pin and bearing. The looseness causing this point at C, in its late release; continuing on the exhaust line to f, it is seen the compression is extremely light for the speed.

Ordinarily the exhaust valve should close at about the point S, and rise on the dotted line up to f, where admission occurs and if the steam valve opens to full port opening it should rise up to full receiver pressure at A′ instead of stopping at A until the piston moves forward.

Wear on the latch block and plate and looseness in connections to wrist plate have most to do with causing the low steam line at A. Considering this condensing diagram, the vacuum is fairly good. Exhaust valves on the low pressure cylinder should close at f and e, to destroy the vacuum in the cylinder and build up the compression as the piston returns.

Corliss engines with only one eccentric do not allow of a wide range of adjustment of these valves and care must be used to keep within this limit. It does not seem that the thick piston is leaking badly enough to require the cylinder to be rebored at the present time. It may be worn somewhat, but proper lubrication will eliminate some of the wear and the worn parts of the valve gear (the latch plates and blocks) should be replaced before they cause serious trouble by not picking up, or opening the valves. Allowing the receiver pressure alternately to rise to dangerous limits and then drop to a low value would cause unsteady speed and constant reaching of the governor to maintain equilibrium, which is not safe with an ammonia compressor. The engine is not in good enough condition to be left alone as it will grow worse rapidly from now on unless the worn parts are renewed.

Cambridge, Mass. R. A. CULTRA.

Potential Power in Small Stream

WHAT IS the maximum power that may be derived from a stream 70 ft. wide and 5 ft. deep, flowing with a velocity of 180 ft. per min., when the available head is 30 ft.? Assume an overall efficiency from water to switchboard of 80 per cent. T. L. J.

A. The energy available from a given quantity of water, w, falling through a height, h, is equal to the product of the two, wh.

Assuming that the 5 ft. depth mentioned is the maximum depth and that the average depth of the stream would probably be about 2½ ft., the cross-sectional area would be about $70 \times 2\frac{1}{2} = 175$ sq. ft. Inasmuch as the

velocity is 180 ft. per min. or 3 ft. per sec., the discharge, which is equal to the product of the area times the velocity, will be $175 \times 3 = 525$ cu. ft. per sec. As there are 62.5 lb. of water in a cubic foot, the flow will amount to $525 \times 62.5 = 32{,}800$ lb. per sec.

The work done then by this water in falling through a height of 30 ft. will be $30 \times 32{,}800 = 984{,}000$ ft. lb. per sec. One horsepower is equivalent to 550 ft. lb. per sec., so that the theoretical horsepower developed will be $984{,}000 \div 550 = 1790$ hp. Allowing for hydraulic and mechanical losses of 20 per cent, the possible net output would be $1790 \times 0.80 = 1430$ hp. or 1070 kw.

Calculation of Power Requirements

WE HAVE a grain elevator that raises 56,000 lb. of grain 100 ft. every 15 min. by means of buckets riveted to a belt. We wish to drive this elevator by an electric motor and would like to know what size motor will be required. The current available is 3-phase, 60-cycle, 220-v. V. K. S.

A. The work done by this elevator is the product of the weight lifted and the distance through which it is raised, or $56{,}000 \times 100 = 5{,}600{,}000$ ft.-lb. This amount of work is done over a period of 15 min., hence the work done in unit time is $5{,}600{,}000 \div 15 = 373{,}333$ ft.-lb. per min.

Power is the rate of doing work and by definition 1 hp. is work done at the rate of 33,000 ft.-lb. per min., hence the actual horsepower required by the elevator is $373{,}333 \div 33{,}000 = 11.4$ hp. This is a theoretical quantity and it is probable that, due to mechanical losses in transmission, the actual motor capacity required will be, say, 20 hp. The electrical power corresponding to this figure will be $20 \times 0.746 = 15$ kw. (approximately).

With a 220-v. circuit, the current required will be $15 \times 1000 \div 220 = 68$ amp. If the motor employed is to use three-phase current, the current per phase will be $68 \div \sqrt{3} = 68 \div 1.73 = 39.5$ amp.

Diesel Engine Maintenance Schedule

IN THE issue of July 1, on page 698, R. H. asks about a maintenance schedule for Diesel engine plants. In arranging such a schedule, the size of the plant and the number of units should be given careful consideration, as they have an important bearing on the subject. Circumstances alter cases; those parts which might require a great deal of attention in one plant would require little in another.

I recall one installation where the exhaust valves seemed to need attention frequently and it was planned to regrind them every two weeks. The operators became so adept at this work that the time consumed in pulling out the cages of the air admission valves, which were over the exhaust valves, was quite an insignificant item. Perhaps this work was done too often, but there seemed to be much trouble from carbon particles dropping on the seats and being pressed into them so that leakage resulted. In another plant having the same type and size of engine, the valves looked well after 3 mo. of service.

It is true that there are so many parts to the Diesel engine, when compared with a steam engine, which add to the time spent in maintenance, that the total amount assumes serious proportions.

In arranging a schedule, we must think first of the parts most vital to the operation of the engine, that is, those which, if not right, will affect its ability to produce power. Under this head may be included pistons, valves, and fuel pump. Afterwards come bearings, cam levers, governors, air compressors, etc. If the plant in question has enough units so that maintenance work can be done during the day time the man in charge is fortunate for it is often the case that this work has to be done nights and Sundays.

Starting with the engine in proper working order, maintenance might proceed along these lines:

Examine pistons and cylinders every six months.

Examine fuel valves and atomizers every month; test setting and regrind if necessary.

Examine exhaust and air admission valves every two months, regrind if necessary.

Test fuel pump valves every 6 mo. and make necessary repairs.

Examine crankpin and main bearings every two weeks and at any time when the crankcase may be opened up.

The oiling system should be examined monthly and the oil drawn off and carefully filtered.

Cam shafts, governors, valve lever arms and other small parts should run for long periods without giving any trouble, but in time their bearings will wear and need adjustment or repair. An examination once a year should suffice for these parts.

If there is a low pressure service pump to bring the fuel oil to the plant it should be carefully overhauled and packed every 6 mo.

Cooling water pumps should be examined every 3 mo.

The air compressor is like a separate engine and should have the valves in the high pressure stage examined and ground every month. On the lower stages, every 6 mo. should suffice. The bearings should be inspected every 3 mo.

It would be impossible to prepare a schedule that would fit every plant and it will be up to the operator to decide just how often the above duties should be attended to. If he knows his engine as a good engineer should, the need of inspection will become apparent when he feels that things are working as they should. By using the schedule given as a guide, the machine cannot go far wrong unless some part breaks from overstrain.

East Dedham, Mass. G. H. KIMBALL.

Change in Furnace Setting

IN REPLY to F. G. F.'s question in the Aug. 1 issue regarding smoke prevention, I would say that the space between the bridge wall and tubes is too great. If he will raise the bridge wall 6 in. so as to leave a space of 14 in. between the bridge and tubes, he will have sufficient draft and better combustion. This will mean a hotter furnace which will be effective in reducing smoke. Dropping the grates about 6 in. in the rear would facilitate firing with wood. E. G. M.

HOLES AND THIN places in the fire are often overlooked in the corners at the front of the furnace and in front of the brickwork between the firing doors. In stoker practice it is well to watch for large air leaks through the coal hopper.

POWER PLANT ENGINEERING

Trade Mark, Reg. U. S. Pat. Office

Published by the Technical Publishing Co.
537 South Dearborn Street, Chicago.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the act of March 3, 1879.

Issued the 1st and 15th of each month. Established over 28 yr.

Subscription price $2.00 a year in the United States and all its possessions. Canada $2.75 a year. All foreign countries $3.50 a year.

Copies of current issue, 15 cents; of back issues, 25 cents.

Copyright, 1923, by Technical Publishing Co.

Member, Associated Business Papers.
Member, Audit Bureau of Circulations.

New York Office, 150 Nassau St.

Circulation of this issue 20,000

CONTENTS

Beaver River Hydroelectric System. By R. T. Livingston. Illustrated 1015

Building Up Efficiency in Small Boiler Plants. By R. C. Demary. Illustrated 1020

Methods Used in Calculating Tank Volumes. By J. H. Pound. Illustrated 1022

Furnace Arrangement for Burning Fuel Oil. By Claude C. Brown. Illustrated 1024

Novel Application of Indirect Heating. By C. H. Thomas. Illustrated 1026

The Mathematics of Life. By W. F. Schaphorst 1028

Prevention of Injuries in Construction Operations. By J. A. P. Crisfield. Illustrated 1029

Will It Pay to Burn Oil Instead of Coal? By N. G. Near. Illustrated 1032

Foreign Developments in Firing Pulverized Fuel. By C. H. S. Tupholme. Illustrated 1033

Inductive Alternating Current Circuits—I. By E. K. McDowell. Illustrated 1037

Electric Motor Drive in the Textile Industry. By Gordon Fox. Illustrated 1040

The Inquiring Engineer 1044

Brooklyn Firm Installs Danish Diesel Engine 1045

The Origination of an Engineer. By H. W. Rose 1046

Development of High Pressure Steam Boilers. By D. S. Jacobus. Illustrated 1047

Letters Direct from the Plant: Solution to Wheatstone Bridge Problem. Preserving Pipe Fittings. Convenient Record for the Pulley Store Room. Grinder with Flexible shaft Has Many Uses. Painting Boiler Prevents Corrosion. Handy Circular Tank Chart. Emergency Gasket from a Shipping Tag. Ordering and Making Repairs. Illustrated 1051

Problems in Operating Power Equipment: Should Well Enough Be Left Alone? Potential Power in Small Stream. Calculation of Power Requirements. Diesel Engine Maintenance Schedule. Change in Furnace Setting. Illustrated 1054

Editorial: Controversial Questions. One Civic Duty of the Engineer 1056

Off Duty 1057

Power Problems Discussed by Steel Engineers 1058

CO Is Determined by an Electrical Method. Illustrated 1059

New Portable Oscillograph. Illustrated 1060

News Notes 1061

Books and Catalogs 1062

Controversial Questions

One of the most fascinating aspects of the profession of engineering in general and power plant engineering in particular is the almost infinite variation possible in the application of a few fundamental principles. There is no such thing as a stock solution of any given type of problem. Each individual case has to be considered in all its ramified phases and decided for itself, on its own merits, other instances to the contrary notwithstanding. Circumstances alter cases and never are they identical in any two cases. Although it cannot be said that the engineering profession is ruled by precedent, each solution of each type of problem increases the knowledge available on that subject and thus enriches the historical background from which valuable suggestions may be derived for methods of attack on similar problems in the future.

New problems are constantly presenting themselves, problems which seem to question the validity of even our almost axiomatic general concepts. What the final answer will be, only the sum total of diversified experience will decide. Wherever there is a possibility for the exercise of judgment on a problem, there is always room for two or more opinions. If these opinions can be gathered together and presented simultaneously, they may serve to shed an extremely valuable light on the subject which may act as a guide for those who have yet their own particular situation to meet.

This is to be the function of a new department. The Inquiring Engineer, which makes its appearance this issue in Power Plant Engineering. The Inquiring Engineer proposes to select such current questions as are of a more or less controversial nature and solicit opinions on them from representative men in the power plant engineering field. If you have ideas on the subject which differ materially from those presented, he would be glad to hear of them. With your co-operation, this inquisitive young engineer will grow and be of ever increasing service to you. Let's give him a good education.

One Civic Duty of the Engineer

Each year sees a growing interest on the part of the general public, in accounts of engineering projects. As a result of this interest, the daily newspapers look upon engineering subjects as having a news value particularly where the projects involved have a local interest or because of the magnitude of the work or its spectacular nature, a national interest.

Unfortunately the accuracy of many of these technical articles is frequently questionable and in some cases the facts are so garbled as to mislead the average reader.

Many instances might be cited from the daily papers to illustrate this point but one example will suffice. In commenting on plans for a new power plant for Johns Hopkins University, a well known Baltimore paper made some interesting statements. For instance the plant, according to this paper, is to develop 300,000 hp. and "while no estimate has been made of the cost it is expected to run well over a million dollars." The coal handling system is evidently to be out of the ordinary for "it will be provided with great overhead coal vaults with a capacity of 100,000 T."

It is not our purpose to poke fun at the newspapers for using such technical fairy tales but rather to point

out a part which the engineer might play in correcting such absurdities.

Usually the engineer reads such accounts with the same spirit as he reads the comic strips. For the average reader, however, the matter may not be dismissed so easily. It is quite natural to assume that such articles are authoritative particularly when the source of the material appears to be from the locality interested, where it would be presumed that the facts could be readily ascertained. Hence the news is spread from Maine to California that a 300,000-hp. plant is to built by Johns Hopkins University; that it will cost probably over a million dollars and that the overhead coal bunkers will hold 100,000 T.

This is not so much a reflection on the daily papers for using the items as it is a reflection on engineers for allowing inaccurate statements to go unchallenged.

If you read an item in your city or community paper which covers a project of local interest and which you know does not give the actual facts, it is your duty as a matter of civic interest to see that it is corrected. Better yet, if you are directly interested in the project see that the newspapers are aided in accurately presenting the story to the public.

Removal of Hazards in Construction Operations

One of the greatest hazards of construction work arises from the fact that practically a new organization is built for each job. The more or less temporary character of the work and the type of labor available for the class of work, make it extremely important that due attention be given to matters of safety.

Engineers having to do with construction work should therefore be interested in the article on this subject by J. A. P. Crisfield, which appears in this issue. As vice-president of a large construction company, Mr. Crisfield is well qualified to discuss this subject and careful observance of the rules which he lays down cannot but result in a decrease in the number of accidents usually met with in this kind of work.

Off Duty

In a recent issue of one of the national weeklies an anonymous writer discusses the hairbreadth differences between success and failure in the lives of men. He analyzes the fine, infinitesimal reasons why men of apparently brilliant mental and physical resources fail to reach the top, or if they do reach it, why they fail to stay there. He illustrates how slender and hidden are the cracks which prevent a man from giving out a loud, clear ring when he is tested by the tap of Destiny's finger nail.

Some people call it luck, and in many cases it is luck. As this writer puts it, nobody but a fool or one who has not observed the careers of prominent men will say that luck, as it is called, does not play a big part in some men's flights. But it is not all luck. The very fineness of the difference between men being hard to see, it is easy to put the blame on luck.

Now, in the same fine way that fate regulates the destiny of human affairs, so also does she regulate the balance wheel of great scientific achievements. Great truths in nature are often so concealed that only a Newton or a Maxwell or an Einstein can uncover them.

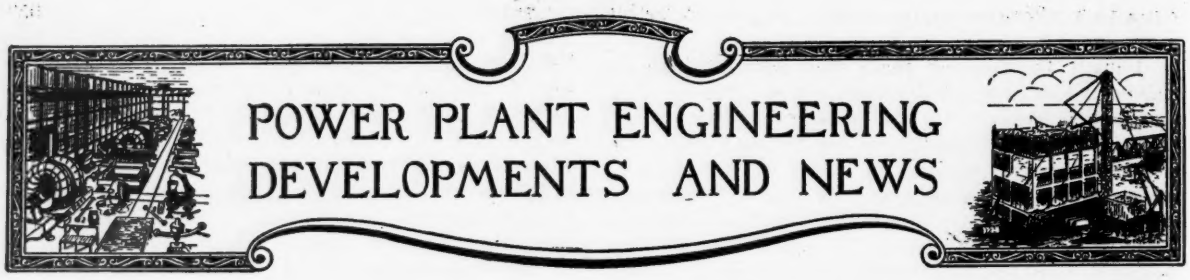
Some years ago, in an address before the British Association, the late Sir Frederick Bramwell drew attention to the practical importance of what he termed "the next to nothings." Thus, an insignificant percentage of phosphorous in steel ruins it; a mere trace of certain gases poisons catalysts. As pointed out in a recent issue of Engineering of London, a striking instance of the importance of these "next to nothings" is afforded by the fact that there appears good reason for believing that the solution of the outstanding mystery of how the sun's heat is maintained is to be found in the circumstance that the atomic weight of helium is 4 instead of 4.0288. In the sun and stars atoms of hydrogen, apparently, are being associated in groups of four to form atoms of helium, and in this process energy is given out which is equal to twice the kinetic energy which would be represented by the loss of mass, if it traveled at the velocity of light. This is so enormous that the energy released in forming 1 lb. of helium would be equal to that liberated by burning 8000 T. of coal.

One of the earliest observations regarding electrical phenomena was that of electrical charges on bodies. It was found that two electrically charged bodies would attract or repel each other according as their charges were of the opposite or of the same kind. Another early observation was that of the attraction and repulsion between the poles of two magnets. Their influence upon each other is transmitted across intervening space in the same mysterious fashion as that of the electrical charges, or of that of the moon and the earth. Yet there is little resemblance between the electrical charge and the magnet.

A connection of a very direct kind, however, was soon discovered. It is revealed when the charge or the magnet is set in motion. The motion of either one of them creates the other, as it were. The electric current as we know it appears to be a kind of a connecting link between static electricity and magnetism. The difference between electrical and magnetic observations was so great that different units were employed to measure electrical and magnetic quantities. It was thus possible to express the value of an electric current either in the electromagnetic or in the electrostatic system of units.

So much being known it naturally became of interest to know the ratio of the electrostatic and the magnetic units in measuring any kind of quantity, and upon investigation it was found that the numerical ratios of the two units for measuring any given quantity, first in electrostatic and then in magnetic units, are always some power of the number expressing the velocity of light. This was the first intimation that the phenomena of light had any direct connection with electrostatics and magnetism. It was this hidden ratio which gave James Clark Maxwell the clue upon which he later built his world famous electromagnetic theory of light and upon which practically all of our present day knowledge of electrical matters is based. It was merely another case of the importance of a "next to nothing."

In science and engineering as in the case of human affairs, the "next to nothings" are the last tiny increments of weight which determine whether the balance swings one way or another. It is up to the engineer and the man of science to find these increments so that when the results of his efforts are being weighed in the balance he may put them into his side of the scale and make it swing towards success and fame, instead of failure and disappointment.



Power Problems Discussed by Steel Engineers

HIGH STEAM PRESSURES, ECONOMICAL USE OF FUEL AND CENTRIFUGAL PUMPS AMONG THE TOPICS CONSIDERED AT 17TH CONVENTION OF IRON AND STEEL ELECTRICAL ENGINEERS

TOPICS which related to the efficient production and utilization of power held the center of attention at the 17th annual convention of the Association of Iron and Steel Electrical Engineers held at Buffalo, Sept. 24 to 28. High steam pressures, the economic use of fuel in the steel industry and operating comparisons between steam and motor-driven centrifugal pumps were subjects which evoked discussion.

Dr. D. S. Jacobus, of the Babcock & Wilcox Co., in presenting his paper "High Pressure Steam Boilers" deviated from his written address in order to give the engineers a more intimate knowledge of some of the problems to be met in the design of high pressure boilers. He stated that those organizations now installing 1200-lb. boilers realized fully that certain features could be worked out satisfactorily only through gradual evolution based on experience.

CONTROL OF SUPERHEAT IMPORTANT

In the present design of 1200-lb. boiler he mentioned that studies made in conjunction with the turbine manufacturers had shown the advisability of a better scheme for the control of the reheating temperatures. It is expected that the reheating superheater will be located so that damper regulation will be possible in order to regulate the temperature of the steam passing to the 375-lb. pressure turbine.

According to Dr. Jacobus the 375-lb. pressure appears to be about as high as it will be practical to go without some method of reheating. In connection with this he pointed out the difficulties to be encountered with inter-stage reheating. A 30,000-kw. unit would require the use of a 24-in. pipe to carry the steam back to the boiler for reheating, since the pressure would be comparatively low; that is, about 125 lb. for a unit using 550-lb. steam. The use of 1200-lb. pressure turbines exhausting at 375 lb. with the reheating of the steam for further use he maintained was a scheme with somewhat less complications than the inter-stage reheating method.

There are such possibilities in the use and development of high pressure equipment that Dr. Jacobus is of the opinion that only experience can show the full economic value. He suggested that it might be possible that multi-stage extraction for heating purposes would aid in the elimination of moisture in the low pressure end of the turbine. In that case a pressure over 375 lb. might prove practical without inter-stage reheating.

H. C. Seibert, fuel engineer for the Bethlehem Steel Co., in his paper on the "Economical Use of Fuel in Steel Plants," pointed out that as the steel industry uses 21.6 per cent of the country's coal, a saving of 10 per cent in this one industry would amount to 10,000,000 T. per year. He showed that the loss in bee-hive coke ovens alone amounted to 7,000,000 T. annually and that even in ovens of modern type a saving of 10 per cent is easily possible. Proper design of blast furnaces, by-product coke plants and power plants was suggested as the remedy.

In commenting on this paper G. R. McDermott, assistant chief engineer of the Illinois Steel Co., stated that it had been their experience that a mixture of producer gas and blast furnace gas could be used for heating plate mill furnaces, using about 40 per cent blast furnace gas in the mixture. For open hearth furnaces a half and half mixture of blast furnace gas and tar is used. He also asserted that it was practical to use blast furnace gas for blowing gas producers by using an air blow for 6 min. and the blast furnace gas for 2 min. There is a gain over steam in this method according to Mr. McDermott due to elimination of moisture.

With the 10-hr. shift coming into use R. B. Gerhardt, assistant general manager of the Sparrows Point plant of the Bethlehem Steel Co., suggested that it might be possible to cast during the 2-hr. interval when the mills were down. This would mean a continuous supply of gas for power purposes during the time the mills were operating.

J. B. Crane, of the George T. Ladd Co., stated that an installation of four 900-hp. boilers is now being made in France which will utilize the heat of a coke cooling system.

MOTOR OR STEAM DRIVE FOR PUMPS?

In taking up the subject of "Motor Operated Centrifugal Pumps in Steel Plants," B. A. Cornwell, electrical engineer, Carnegie Steel Co., stated that there is no satisfactory comparison between the electric motor and gas or steam engine drive for centrifugal pumps. The first cost, maintenance and attendance is considerably less, the simplicity and the reliability much superior and the power cost ranges from 25 to 50 per cent less.

Some opinions on this differed as Mr. Barrington cited an instance where pumping costs were 11 cents per million gallons more with electric drive than with steam. This particular installation consists of two 18,000,000-gal. pumps, one driven by a motor drive with a current cost of 1.1 cents per kw.-hr. and the other pump driven by a condensing turbine with a steam cost of 26 cents per 1000 lb. It was his belief that steam pumps were

frequently located too far from the source of steam supply with a result that radiation losses were too high.

Overload Guarantee Desired for Motors

A. L. McHugh, chief engineer of the Gould Pump Co., brought up the point that the present method of rating motors is not satisfactory from the pump manufacturers' viewpoint. In getting away from the former 40 and 50 deg. ratings the new rating scheme adopted by the Power Club is to rate a motor on a 40-deg. rise basis but without a guaranteed overload capacity. Mr. McHugh asserted that due to a falling off in head a centrifugal pump was frequently overloaded for short periods. The motor could, however, be applied on the basis of full load giving the maximum efficiency and best power factor at that load provided the rating permitted the overload condition. He suggested a return to the old 40-deg. rating where a 2-hr. overload was guaranteed with a maximum temperature rise of 55 deg. C.

Many other interesting papers were presented dealing with the various problems of the electrical engineer in the iron and steel industry. The exhibit held at the Broadway Auditorium was also one of the features of the convention.

Officers of the association for the ensuing year were elected as follows: President, R. S. Shoemaker, Middletown, O.; vice-president, A. C. Cummings, Pittsburgh; secretary, J. F. Kelly, Pittsburgh; treasurer, James Farrington, Steubenville, O.

CO Is Determined by an Electrical Method

DETERMINATION of the percentage of carbon-monoxide or CO in the flue gas through the use of an electrical method is a recent development of the Bacharach Industrial Instrument Co., of Pittsburgh, Pa.

Operation of the meter is based on the catalytic action of a heated platinum wire in producing combustion of CO with oxygen. Referring to Fig. 1, "A" and "B" are two small platinum wires, each passing through the center of cylindrical chambers in two separate metal blocks. "B" is the comparison wire, and "A" is the measuring wire in the chamber through which the sample of flue gas passes slowly. The wires are heated to a temperature of about 800 deg. F. by an electric current.

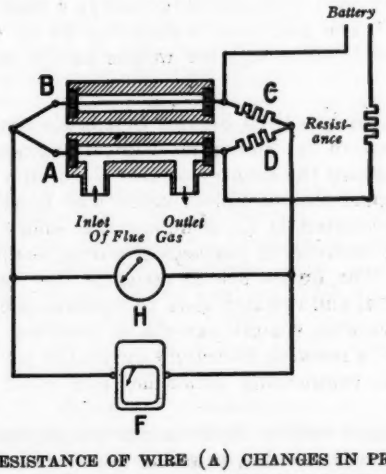


FIG. 1. RESISTANCE OF WIRE (A) CHANGES IN PROPORTION TO AMOUNT OF CO AND HYDROGEN PRESENT

Usually enough oxygen is present in the waste gases for the combustion of the CO and hydrogen; but to make certain of this, air to the amount of 20 per cent of the gas volume is admitted through the small passage E, Fig. 2. The catalytic action causes the CO and H_2 to burn along the surface of the wire "A," thereby raising its temperature and increasing its resistance in almost exact proportion to the amount of these gases present. When considerable amounts of CO are present, the wire is heated to a brilliant glow. As "B" maintains constant temperature and resistance, the Wheatstone Bridge circuit, consisting of the wires "A" and "B" and the resistances C and D, becomes unbalanced, and causes an indication on the galvanometers F and H.

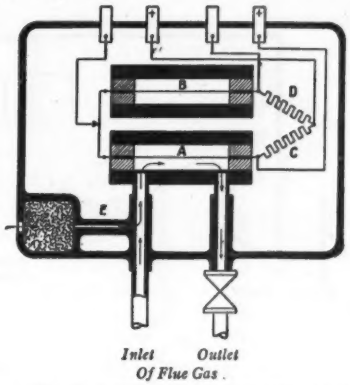


FIG. 2. AIR IS ADMITTED THROUGH PASSAGE E

These instruments are calibrated in percentage of CO or CO plus H_2. As the combustion heat of a given volume of H_2 is almost identical with that of CO, the CO meter may serve for a mixture containing both gases. For boiler house practice, it is not necessary to know what fraction of the sum is CO and what fraction is H_2; the important thing is the indication that these combustibles are present and to what extent combustion is incomplete. Methane or other hydrocarbons are not indicated, but they occur only in small quantities except where the CO content is extremely high.

To some extent the catalytic effect is dependent on the velocity with which the gas flows past the wire "A." As the electrical CO meter is mostly used in addition to an electric CO_2 meter (described in the Aug. 15 issue), the dimensions in the CO meter are chosen to be in accordance with medium rate of gas flow; this flow being the same as the one streaming through the CO_2 meter; changes of as much as 100 per cent in this rate of flow have practically no influence. The effect of difference in heat conductivity due to CO_2 is present in the CO meter just as in the CO_2 meter; this effect is in the CO meter so completely overbalanced by the catalytic action that even the highest percentage of CO_2 possible in boiler waste gases has less influence than 1/10 per cent of CO.

Arrangement of the CO meter with accessories, and combined with a CO_2 meter is shown in Fig. 3. The gas sample is drawn in continuously by an aspirator

through a cooler around which circulates the water going to the aspirator; from there the gas passes through the water filter to the throttle disc and to the CO_2 meter which is equipped with a small control filter and a manometer for checking the velocity of the gas sample; thence to the CO meter and the aspirator.

The galvanometer H (Fig. 1) is a waterproof well type instrument suitable for mounting on the front of the boiler and F is a recorder usually placed in the superintendent's office. The multiple recorder may be used to record on the same chart the CO and the CO_2

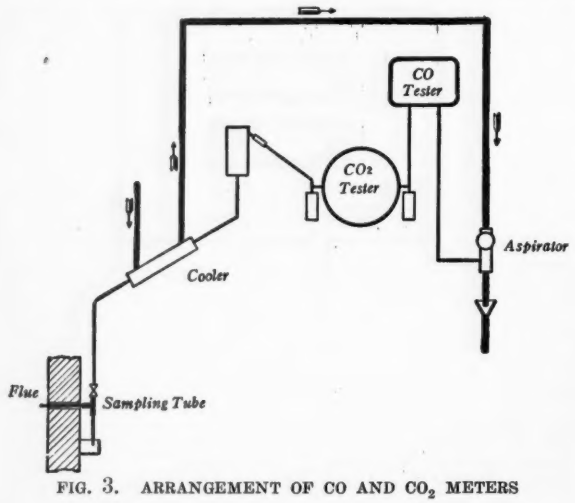


FIG. 3. ARRANGEMENT OF CO AND CO_2 METERS

contents of the waste gases of as many as three boilers.

It is necessary to supply a terminal voltage of 2.7 for the CO meter and the current passing through the Wheatstone Bridge of the CO meter amounts at this voltage to 0.85 amp. To supply this current, a storage battery may be used or the CO meter may be connected to a d.c. line of 120 or 240 v.; in both cases a resistance of suitable amount must be provided in series with the CO meter to keep the current within the given limit of 0.85 amp.

In general, the indications of combustible gases by this instrument are accurate within a few tenths of one per cent. Greater accuracy than this cannot be expected, and in practice is not necessary. What is required is a sure indication that combustible gases are being wasted, and this the CO indicator cannot fail to show, if correctly installed.

New Portable Oscillograph

RAPID strides in electrical advancement have been made possible with the help of the oscillograph, but with the expansion of the field of electric railways, great interconnected power system, etc., there has been an increased need for an oscillograph outfit that would be portable and that would work just as well in the field as in the laboratory. While there have been more or less portable instruments of this type available for some time past, they have been bulky and inconvenient to move about. The Westinghouse Electric and Manufacturing Co. has recently developed a portable oscillograph that is extremely compact, but yet will cover a broader field of work and is more easily operated than the earlier, more bulky instruments.

This new oscillograph is complete in one unit except for the motor and film holder. The main unit is 11 in. wide, 11½ in. high and 25 in. long and includes the entire optical system, special incandescent lamp illuminant, a highly sensitive three element galvanometer, complete control equipment for vibrator elements (including 30,000 ohms of non-inductive resistors), and a transformer (for operating the lamp and motor) for 110 or 220 v. supply at any frequency from 25 to 70 cycles.

A special lamp control switch and automatic lamp-extinguishing switch enable the operator to apply a greatly abnormal voltage to the incandescent lamp to obtain results equal to those formerly secured only with the intense light of an electric arc. With this automatic control the same lamp can be used for hundreds or even thousands of oscillograms since the lamp is at greatly abnormal voltage only for a small fraction of a second during the exposure. The galvanometer is of the latest construction and is equipped with supermagnets of a newly developed permanent type which make the

GENERAL ASSEMBLY OF WESTINGHOUSE PORTABLE OSCILLOGRAPH WITH MOTOR AND FILM HOLDER

vibrators more sensitive than with any previous electromagnets. This new construction does away with the necessity for a field-rheostat, ammeter, control switches, storage battery and rectifier.

Also included with the outfit is a special film holder that can be loaded and unloaded without going into a dark room. It takes standard kodak films which can also be developed without a dark room in a tank developing outfit. The main unit weighs but 80 lb. complete and the whole outfit together weighs hardly more than 100 lb.

UNITED STATES Civil Service Commission announces an examination for junior mechanical engineer, to be held throughout the country on Nov. 7, to fill a vacancy in the Department of Construction and Repair, Navy Yard, Washington, D. C., at an entrance salary of $5.04 a day, and vacancies in positions requiring similar qualifications. The duties are to assist in the conduct of experimental and research tests, to perform calculations, design apparatus, compile reports, or otherwise assist in the work of a research laboratory devoted to the study of mechanical engineering problems, and other related work.

Competitors will be rated on general physics, mathematics through calculus, practical questions in mechanical engineering, and education, training, and experience. Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the post office or customhouse in any city.

News Notes

STONE & WEBSTER, INC., of Boston, has opened an office in Cleveland, O., at 1431 Leader Building. The office is in charge of J. R. Hammond as district manager of construction and engineering.

E. D. SPICER, Wellsville, N. Y., has resigned his position as works manager of the Kerr Turbine Co. to become general manager of the Standard Turbine Corporation, of Wellsville, N. Y.

J. B. CRANE, sales manager of the George T. Ladd Co., Pittsburgh, Pa., addressed the M. E. Cooley Association No. 7 of the National Association of Stationary Engineers at Detroit, Mich., Sept. 6. His subject was "Large Water Tube Boilers."

WARREN, WEBSTER & Co. announces the opening of an office in Des Moines, Ia., at 708 West 34th St. It will be operated as a branch of the Chicago office, and will be in charge of Hugo R. Sindelar, who has been with the Chicago office for a number of years.

PACKARD ELECTRIC Co., Warren, O., is erecting a new transformer plant which will double its transformer production capacity. Ratings will be built up to 7500 kv.a. The old plant is to be remodeled and devoted to the production of automotive cable.

WALTER A. DEEMS, for the past 10 yr. master mechanic of the Baltimore & Ohio's New York terminals and the Staten Island Rapid Transit Co., has joined the Machine Tool Department Sales Organization of Manning, Maxwell & Moore, Inc., with headquarters at 100 East 42nd St.

AT THE SERVICE GROUNDS of the Edison Electric Illuminating Co., of Boston, Mass., on the evening of Sept. 13, a spectacular celebration was held by some 4000 employes and guests from the territory served by the company in observance of a connected load of 500,000 kw. Aug. 29 was the first time the company has passed the half million mark.

KATAHDIN ELECTRIC Co. has been incorporated and will establish a plant at Patten, Me. The company is authorized to issue capital stock to the amount of $50,000. Raymond D. Gardner is president and Verdi Ludgate is treasurer and clerk of the corporation. Under its articles of incorporation, the company is authorized to generate and supply electricity in certain towns in Penobscot County, Me.

TEMPLETON MANUFACTURING Co., Hyde Park, Mass., has been taken over by The Sterling Engineering & Manufacturing Corporation, which will continue to manufacture the Sterling return trap and Sterling separating trap at the same location. The officers of the corporation are: Charles G. Stebbins, president; Paulsen Spence, vice-president, and C. Curtis Tracy, treasurer and general manager.

LOUIS A. FERGUSON, vice-president in charge of operation of the Commonwealth Edison Co., Chicago, has been in the service of that and predecessor companies 35 yr. At the Drake Hotel, Chicago, on the evening of Sept. 12, 1923, 300 Edison men who have been associated with him upwards of 10 yr. commemorated the event with a dinner in his honor. A memento presented at the time was a book of morocco and vellum containing the signatures of a thousand men and women who have served with him for a decade or more. Another remembrance of the anniversary and presented to him at the dinner was an eight-piece silver service, the gift of the signers of the book. The dinner, the service, and the book of signatures mirror the esteem in which the man is held by his associates and his company.

EIGHT Westinghouse new model multiple retort underfeed stokers recently purchased by the West Penn Power Co for its Springdale, Pa., plant will be driven by eight two-speed, three-phase motors complete with slide rails and controllers. Sixteen three-phase squirrel cage rotor motors have also been ordered to drive the rolls on the rotary ash discharge devices. These motors are actually capable of developing two maximum and two minimum speeds, thereby giving a 4 to 1 speed ratio through two sets of poles, the stoker motors having 6 and 12 poles respectively and the grinder motors having 5 and 18 poles respectively.

CONSTRUCTION of most modern type is represented in the new base load generating station now being erected at Middletown, on the Susquehanna River about 14 mi. below Harrisburg, as part of the system of the Metropolitan Edison Co. The new station will have an ultimate capacity of 180,000 kw. and will cost approximately $20,000,000. The first unit, on which work is well advanced, will represent an outlay of about $4,000,000 and is expected to be ready for operation late in the summer of 1924. It will have a capacity of 30,000 kw. Five boilers will be required to generate steam for the operation of the turbine. The boilers will be fired with pulverized coal. Much of the coal supply will be dredged from the Susquehanna River.

NOT FOR SOME years have water power been at such a low level as it is at the present time throughout many sections of New England and as a result many power plants and manufacturing concerns are forced to curtail production. Rivers in Massachusetts, including the Nashua, Connecticut, Merrimac and Deerfield Rivers and their branches, are at low level. New Hampshire is similarly affected, while in Maine many plants depending largely on water power are seriously curtailed.

UNITED STATES Civil Service Commission announces an examination for assistant mechanical engineer (internal combustion engines). Receipt of applications will close Nov. 6. The examination is to fill a vacancy in the Bureau of Aeronautics, Navy Department, at an entrance salary of $6.40 a day, and vacancies in positions requiring similar qualifications, at salaries ranging from $2000 to $2400 a year.

Applicants must have been graduated in engineering, preferably mechanical engineering, from a college of recognized standing, and have had at least 2 yr. experience or postgraduate work in mechanical engineering as it applies to the design, construction or testing of internal combustion engines for automobiles or aircraft. Competitors will not be required to report for examination at any place, but will be rated on their education, experience and fitness on the scale of 100, such ratings being based upon competitors' sworn statements in their applications, and upon corroborative evidence. Full information and application blanks may be obtained from the U. S. Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the post office or customhouse in any city.

Books and Catalogs

PRACTICAL ENGINEER MECHANICAL POCKET BOOK, 1923, edited by Ernest G. Beck; 622 pp., 3½ by 5½ in., cloth; London, Special Magnolia Edition.

This, the thirty-fifth edition of this little book, has been revised and a considerable quantity of new material added with the idea of making it better adapted to the needs of the practical engineer. The volume includes informtion on steam and its generation, engines and turbines, condensers, gas and oil engines, compressors, heating and ventilating, hydraulic machinery, strength of materials, machine tools, piping, power transmission, etc. A chapter on miscellaneous subjects includes some epitomized data on refrigeration, workshop design, cranes, springs, welding, forging furnaces, etc. The material is largely of a rule-of-thumb nature.

LENTZ POPPET VALVE ENGINES are covered in bulletin No. 600-A now being distributed by Erie City Iron Works of Erie, Pa. This engine makes use of the double seat poppet valve, the steam regulation being accomplished by varying the cutoff through a shaft governor and straight slot eccentric instead of by throttling. The first Lentz engine was built in Germany in 1899 and since that time it is said that four million horsepower in units of this type have been installed. In 1909, the Erie City Iron Works obtained the rights for this engine. Steam consumption and efficiency curves, together with other general test data are presented in the bulletin and a discussion of the principles of prime mover selection is also given.

CHAPMAN VALVE MFG. CO., of Indian Orchard, Mass., has issued a reprint of Discussion by V. T. Malcolm, metallurgical engineer for the Chapman organization, in which he comments on a paper, "The Commercial Economy of High Pressure and High Superheat in the Central Station," which was presented by George A. Orrok before the American Society of Mechanical Engineers. Mr. Malcolm, in his comments, gives the results of tests which have been conducted to show the effect of high temperatures on the physical properties of metal used in valve construction.

EVERLASTING VALVES are illustrated and described in catalog No. 17 recently issued by the Everlasting Valve Co., of Jersey City, N. J. One of the features of this booklet is a description of the new "Flatplug" valve. In this type of valve the seat is merely pushed into place by hand and not held fast by screw threads or other like fastening. When the valve is assembled, the seat is held in proper place by a disc and spring. This arrangement permits of easy repair although the valve is said to stay tight for long periods of service.

TWO TYPES of under-voltage relays, which provide adequate protection of apparatus from damage caused by sudden return of supply voltage after its failure or reduction are described in Bulletin No. 47,635 issued by the General Electric Co.

These relays, known as types PQ-25 and PQ-26, are used for tripping electrically operated circuit breakers when the voltage has decreased to a certain predetermined value; for automatically disconnecting motors on under voltage, thus preventing them from restarting unexpectedly on return of voltage with possible damage to driven machines, and in any case where it is desirable to operate an auxiliary circuit on the occurrence of a decrease in voltage. The relays are of the self-resetting plunger type and may be supplied for operation on either direct or alternating-current control. Type PQ-25 is for single-circuit control while type PQ-26 is for two-circuit control. The former is made in two forms, instantaneous pick-up and time delay drop-out, or instantaneous pick-up and drop-out. The latter is made in one form only, instantaneous pick-up and drop-out.

CENTURY ELECTRIC Company, of St. Louis, Mo., has recently issued a booklet describing its type SC induction motors.

POLYPHASE INDUCTION MOTORS are covered in bulletin No. 1118-B published by the Allis-Chalmers Mfg. Co., of Milwaukee, Wis. These motors, knowns as type AR, range in ratings from ½ to 200 hp. Details of construction are described and illustrated.

JONES SPUR GEAR SPEED REDUCERS are covered in catalog No. 26 recently issued by the W. A. Jones Foundry & Machine Co., of Chicago, Ill. Considerable technical and practical information, as well as descriptive matter and illustrations of typical drives, are presented in this catalog.

IN THE GENERAL CATALOG recently issued by the American Blower Co., of Detroit, the line of fans for heating, ventilating, air conditioning, mechanical draft, drying, mine ventilation, air blast systems and other such uses are described and illustrated. This 102-page catalog is arranged so that it can be used for the preliminaries of estimating work.

HENRY WELLS Oil Co., of 11 Haymarket, London, has recently issued two booklets describing the "Germ Process" manufacture of lubricating oils. This is a process involving the addition of certain substances to oils for the purpose of lowering the surface tension of the oil. This, according to the inventors of the process, increases its value as a lubricant.

JOS. W. HAYS CORP., of Michigan City, Ind., is distributing a leaflet which describes its new model automatic CO_2 and Draft Recorder. It is stated that the principles of operation have been simplified; that the recorders are more rugged and the parts are more accessible. The steel caustic tank has also been enlarged so that only three renewals per year are required.

ATWOOD & MORRILL Co., Salem, Mass., is now distributing two new catalogs. Catalog D covers exhaust steam valves for turbine and condenser service. Catalog E covers the general line of steam specialties including reducing valves, steam traps, automatic receiver and pump governors, back pressure valves, cast iron exhaust heads, balanced lever valves, damper regulators, pump governors, tank valves and strainers.

HOMESTEAD VALVE MFG. Co. is now distributing literature on the B. & O. protected seat valves which are now being built by the Homestead organization. In this valve a disc sleeve and raised seat protect the ground surface which form a tight seat when brought to a closed position. Any wiredrawing therefore occurs on this sleeve and raised seat rather than on the valve seat proper. This line of valves was formerly manufactured by the B. & O. Protected Seat Valve Co., which was recently taken over by the Homestead Co.